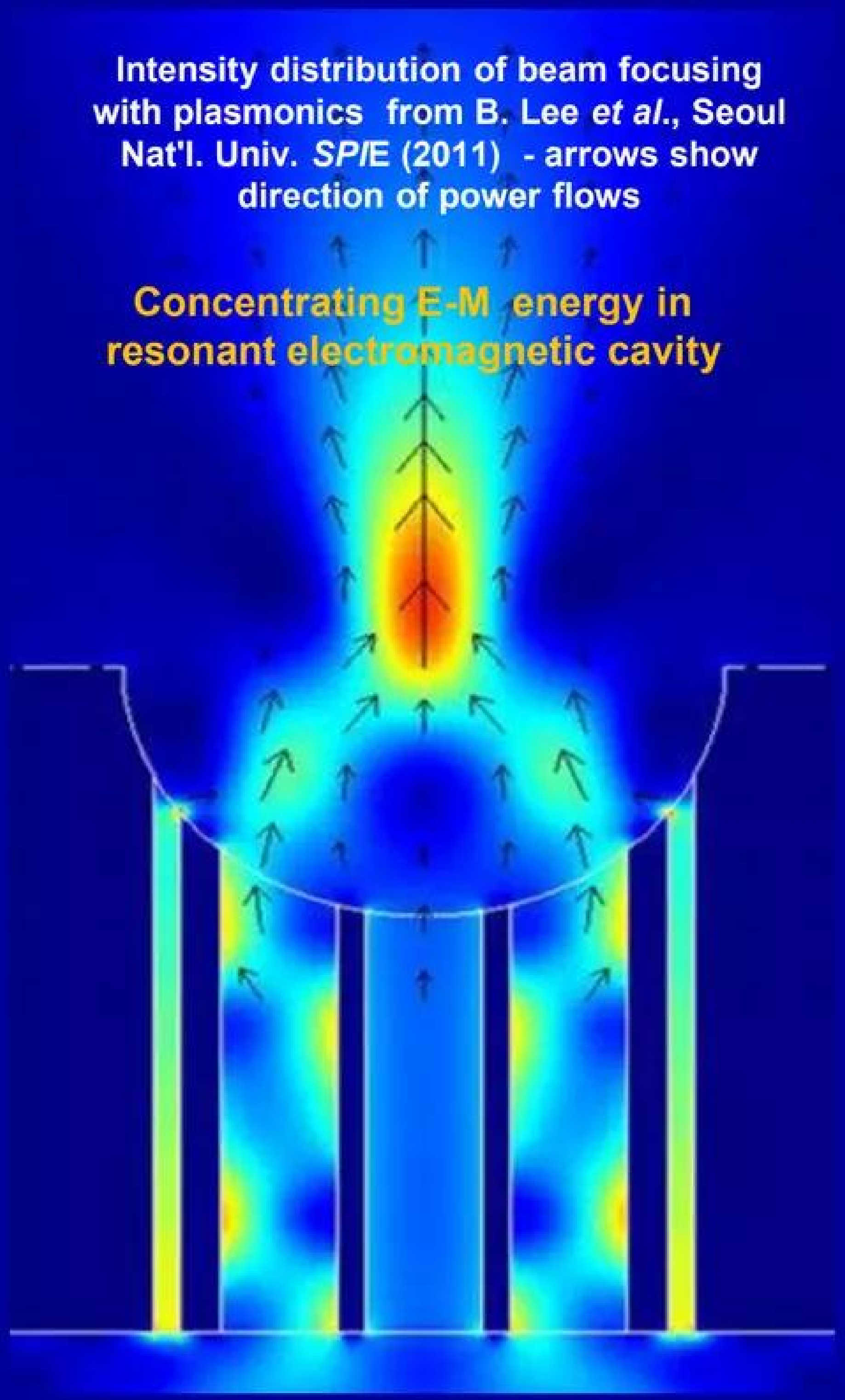
Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

Surface plasmons on Graphene are confirmed

New experimental data in *Nature* supports our hypothesis



Intensity distribution of beam focusing with plasmonics from B. Lee *et al*., Seoul Nat'l. Univ. *SPIE* (2011) - arrows show direction of power flows

Concentrating E-M energy in resonant electromagnetic cavity

http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf

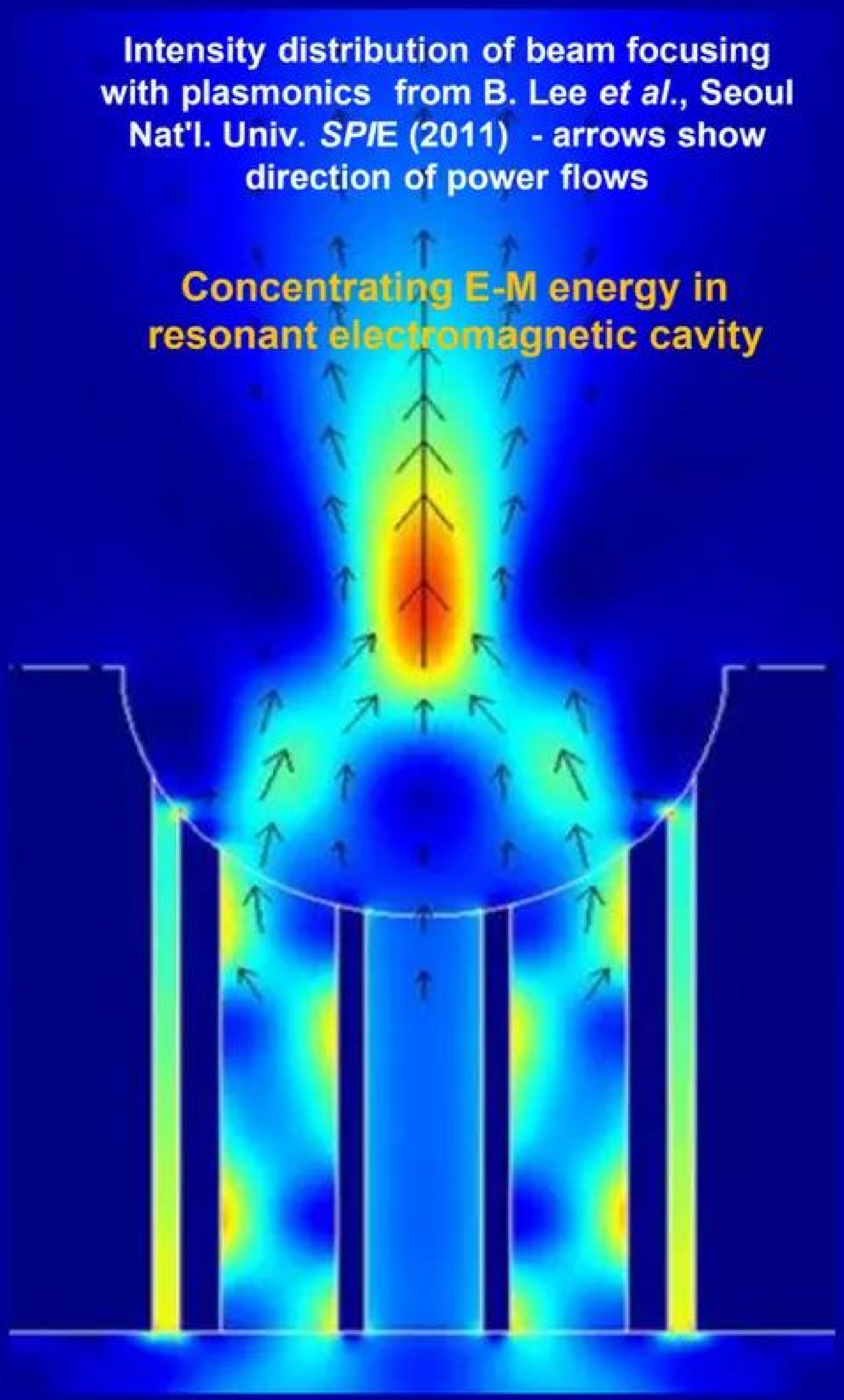
Technical Update

Lewis Larsen, President and CEO

July 6, 2012

Along with quite a number of other like-minded researchers working in plasmonics, we had also hypothesized that surface plasmon electrons existed on the surface of Graphene Carbon sheets and said so publicly in a Lattice Energy LLC SlideShare presentation concerning operation of Carbon-seed low energy neutron reaction (LENR) networks in condensed matter systems dated Sept. 3, 2009. *New papers by two teams just published in Nature have solidly confirmed that speculative conjecture.*

In conjunction with experimental confirmation of breakdown of the Born-Oppenheimer approximation on surfaces of Graphene (2007) and Carbon nanotubes (CNTs - 2009), this development is significant because it implies that the Widom-Larsen theory in condensed matter applies to such materials and that under the proper conditions LENRs can be triggered on hydrogenated CNTs and Graphene surfaces decorated with engineered 'target' nanoparticles in manner similar to cases of 'proton-loaded' metallic hydrides and catalytic hydrogenation of polycyclic aromatic hydrocarbons (e.g. Phenanthrene - Mizuno, 2008).



Intensity distribution of beam focusing with plasmonics from B. Lee *et al*., Seoul Nat'l. Univ. *SPIE* (2011) - arrows show direction of power flows

Concentrating E-M energy in resonant electromagnetic cavity

http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf

Background and objectives of this presentation

New experimental data: surface plasmons now directly confirmed on Graphene

✓ Independent, substantially similar LENR experiments were conducted by two teams, one at Texas A&M University (USA) and other at Bhabha Atomic Research Center (BARC - India) with high-current electric arc discharges between two ultrapure Carbon rod electrodes in ultrapure water (ordinary H_2O). Both groups observed essentially the same anomalous post-experiment results; namely, that stable metallic elements (both reported detecting substantial amounts of Fe; BARC also found detectable Ni, and Cr) that had not been previously present anywhere inside apparatus and appeared to have somehow been created *ab initio* during arcing processes. Detailed mass-balance analyses of Fe, the most abundant apparent product, strongly suggested that elemental Iron (Fe) with ~normal isotope ratios had somehow been created during experiments. Since chemical processes cannot create new stable elements where no such elements had been present before, either both teams' experimental observations were erroneous, and/or contamination may have occurred, or nuclear transmutation processes had produced the observed results

✓ Both teams' reported data were published in 1994 as two papers in a peer-reviewed journal, *Fusion Technology* (American Nuclear Society). To explain their incredible data, the Texas A&M team further proposed a highly speculative and physically improbable heavy element fusion mechanism: $2\ {}_{6}C^{12} + 2\ {}_{8}O^{18} \rightarrow {}_{26}Fe^{56} + {}_{2}He^{4}$. This conjectured "cold" fusion mechanism was not generally believed by the nuclear physics community; thus these retrospectively important experimental results simply languished, largely ignored and still unexplained, until 2009

✓ In a Lattice SlideShare presentation dated Sept. 3, 2009, we applied Widom-Larsen theory of LENRs (WLT) to finally explain these *ca.* 1994 experimental results (for readers' convenience. selected slides from it are included herein without alteration). As readers will recall, WLT requires presence of collectively oscillating surface plasmon electrons (SPs - or their dynamical equivalents) on substrates capable of supporting many-body surface 'patches' of protons on their surfaces and on which the Born-Oppenheimer approximation breaks down which enables creation of nuclear-strength local electric fields. Since no metals were present inside the apparatus at beginning of the 1994 experiments, there was theoretical challenge to explain exactly how WLT's conditions for LENRs were fulfilled therein. With benefit of new knowledge unknown to the researchers back in 1994, namely that copious quantities of carbon nanotubes (CNTs) and Graphene are formed during carbon-arc electrode discharges in water, in 2009 we hypothesized that surface plasmons exist on CNTs and graphene. As of 2009, there was already strong published experimental evidence for SPs on CNTs, however direct experimental evidence for *controllable* SPs on Graphene was still lacking. Well, thanks to papers just published in 2012 by two independent teams in *Nature*, that remaining issue has been decisively clarified: researchers have now directly resolved gate-tunable, propagating surface plasmons in real space on Graphene

✓ Herein, along with other recent discoveries, we will cite the *Nature* papers and discuss implications for LENRs on carbonaceous substrates

Contents

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Commercializing a Next-Generation Source of Safe Nuclear Energy

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Condensed matter: Widom-Larsen theory technical papers

"***Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces***"
Eur. Phys. J. C **46**, pp. 107 (March 2006) Widom and Larsen – initially placed on arXiv in May 2005 at http://arxiv.org/PS_cache/cond-mat/pdf/0505/0505026v1.pdf; a copy of the final *EPJC* article can be found at: http://www.newenergytimes.com/v2/library/2006/2006Widom-UltraLowMomentumNeutronCatalyzed.pdf

"***Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces***"
http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf (Sept 2005) Widom and Larsen

"***Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells***"
http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf (Feb 2006) Widom and Larsen

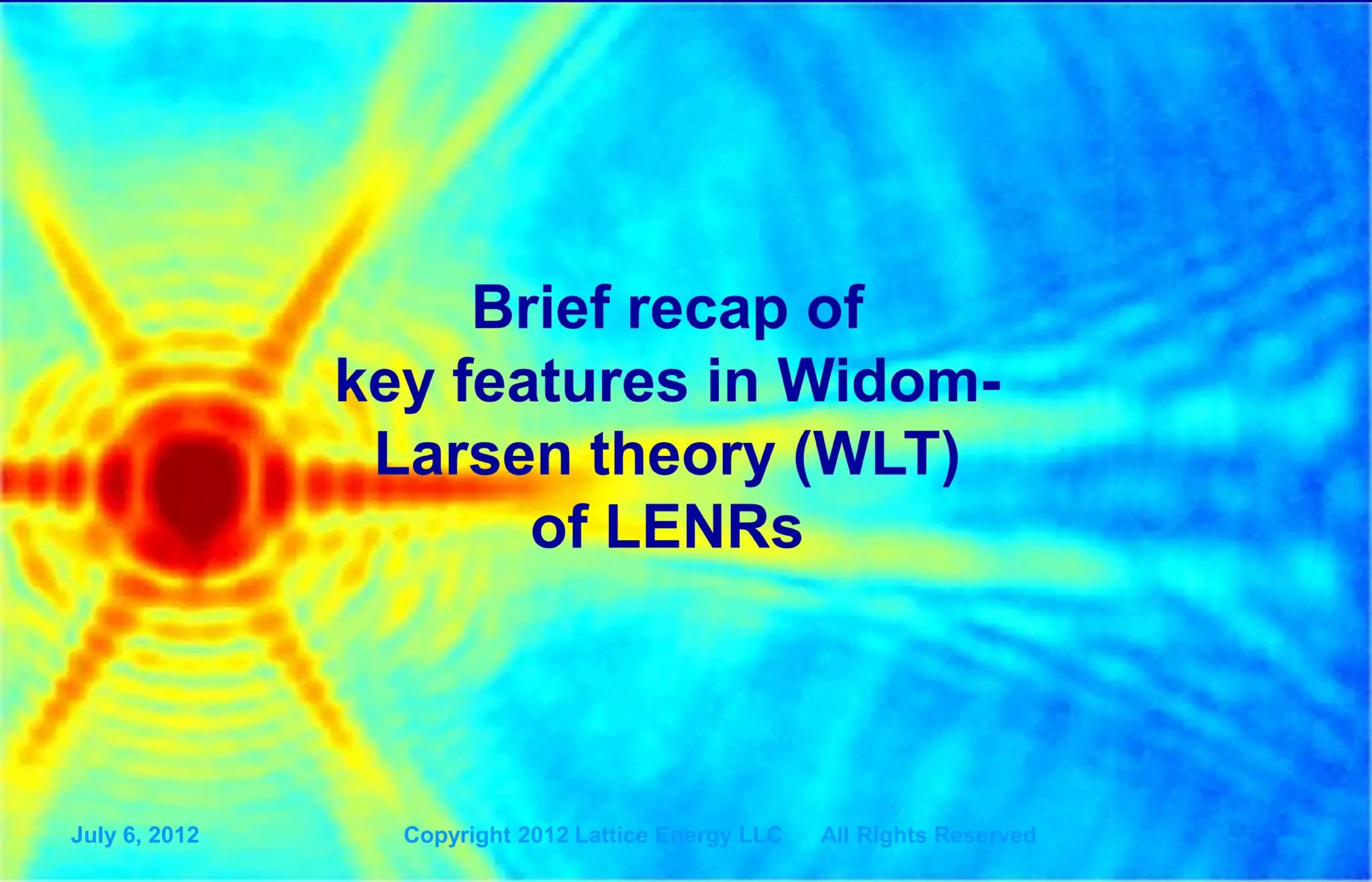
"***Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces***"
http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf (v2. Sep 2007) Widom and Larsen

"***Energetic electrons and nuclear transmutations in exploding wires***"
http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf (Sept 2007) Widom, Srivastava, and Larsen

"***Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary***"
http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf (Feb 2008) Widom, Srivastava, and Larsen

"***High energy particles in the solar corona***"
http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf (April 2008) Widom, Srivastava, and Larsen

"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen
Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf



Brief recap of key features in Widom-Larsen theory (WLT) of LENRs

What is needed to trigger LENRs per Widom-Larsen theory?

Following list outlines what WLT says is necessary in condensed matter

- ✓ **Metallic substrates: substantial quantities of Hydrogen isotopes must be brought into intimate contact with 'fully-loaded' metallic hydride-forming metals; e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc.; please note that collectively oscillating, very roughly 2-D surface plasmon (SP) electrons are intrinsically present and cover exposed surfaces of such metals. At 'full loading' occupation of ionized Hydrogen at interstitial sites in bulk metallic lattices, many-body, collectively oscillating 'patches' of protons (p^+), deuterons (d^+), or tritons (t^+) will then form spontaneously at random locations scattered across metal hydrides' surface interfaces;**

- ✓ **And/or certain Carbon substrates: delocalized, many-body collectively oscillating π electron plasmons that comprise outer 'covering surfaces' of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, Q-M 'entangled' quantum systems that, within the context of the Widom-Larsen theory of LENRs, are functionally equivalent to and behave dynamically like 'loaded metallic' hydrides;**

- ✓ **Breakdown of Born-Oppenheimer approximation: in both cases above, occurs in tiny surface 'patches' of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or alternatively delocalized π electrons and nearby hydrogenous ions; 'patches' create their own local nuclear-strength electric fields; effective masses of coupled 'patch' electrons are then increased to a significant multiple of an electron at rest ($e^- \rightarrow e^{-*}$) that is determined by required simultaneous energy input(s); and**

- ✓ **Input energy: triggering LENRs requires external non-equilibrium fluxes of charged particles or E-M photons that transfer input energy directly to many-body SP or π electron plasmon 'surface films.' Examples of such external energy sources include (they may be used in combination): electric currents (electron 'beams'); E-M photons (e.g., emitted from lasers, IR radiation from resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across 'surfaces'; currents of other ions crossing the SP 'electron surface film' in either direction (ion 'beams'); etc. Such sources provide additional input energy required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^{-*} + p^+$, $e^{-*} + d^+$, or $e^{-*} + t^+$ electroweak reactions.**

- ✓ **N.B.: please note again that surface plasmons are collective, many-body electromagnetic phenomena closely associated with both Q-M entanglement and interfaces. For example, they can exist at gas/metal interfaces or metal/oxide interfaces. Thus, surface plasmon oscillations will almost certainly be present at contact points between purely metallic surfaces and any adsorbed surface 'target' nanoparticles composed of metallic oxides, e.g., PdO, NiO, or TiO_2, etc., or vice-versa between oxide surface and adsorbed metallic NPs.**

WLT has criteria that can identify suitable LENR substrates

In 2009 thought fullerenes/graphene were suitable; graphene SPs now confirmed

- ✓ WLT specifies that a likely to be LENR-active substrate is one that : can ad- or ab-sorb hydrogen isotopes; adsorb various types of nanoparticles on its surface; support many- body collective oscillations of effectively Q-M ‘entangled’ electrons, i.e., surface plasmons (SPs) or their delocalized π dynamical equivalents; allows ‘full loading’ of hydrogen isotopes such that many-body, collectively oscillating, effectively entangled, isotopically homogeneous ‘patches’ of charged protons, deuterons, or tritons can form on its surfaces or at interfaces; and the Born-Oppenheimer approximation breaks down on its surface, which allows nuclear-strength local electric fields to arise in ‘patches,’ spontaneously triggering electroweak neutron production once certain isotope specific field-strength thresholds are exceeded

- ✓ Since 2005, hydride-forming metals have been known to fulfill WLT’s stated requirements for LENR substrates. What became clear *ca.* 2008 in aftermath of Mizuno’s seminal LENR experiments with Phenanthrene was that Carbon aromatic ring molecules, e.g., Benzene and PAHs, might also serve well as LENR substrates. In Sept. 3, 2009 Lattice presentation, we hypothesized that fullerene and graphene molecular structures were also suitable LENR substrates, but direct evidence for SPs on Graphene was lacking then; Graphene SPs just now confirmed

- ✓ Per above, WLT provides materials science guidance and powerful conceptual tools for LENR experimentalists: as people who have read our publications know, nanoscale many-body collective electromagnetic and quantum mechanical effects are a crucial component of WLT; very high local electric fields and Q-M effects are especially important in the WLT condensed matter regime on small length-scales. Importantly, no “new physi*cs*” is invoked *anywher*e in our work; the novelty in our conceptual approach is to integrate many-body collective effects and other existing, well-accepted physics with modern electroweak theory under the ‘umbrella’ of the Standard Model. Importantly, WLT provides materials science guidance as well as plausible explanations for previously inexplicable experimental results: e.g., occurrence of non-stellar, nuclear transmutation processes in condensed matter under relatively ‘mild’ conditions (vs. cores of stars and supernovae) such as in experiments involving electrolytic chemical cells and Carbon-arc discharges described in the 1994 *Fusion Technol*ogy papers

LENRs and chemical processes can occur side-by-side

Condensed matter surfaces: complex 'witches brew' w. many parallel processes

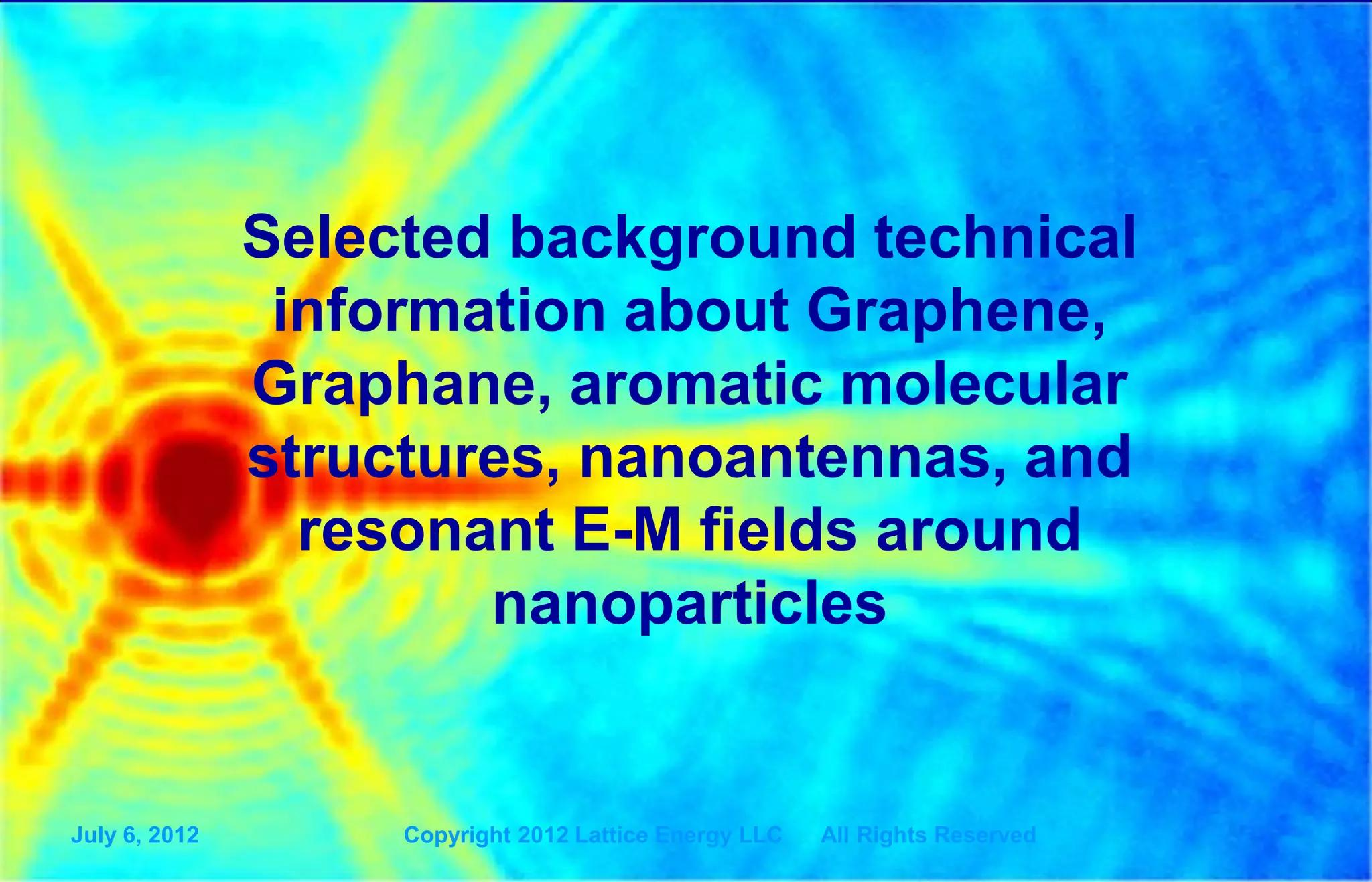
- LENR 'hot spots' create intense local heating and variety of readily noticeable surface features such as 'craters'; over time, LENR-active surfaces inevitably experience major micron-scale changes in local nanostructures and elemental/isotopic compositions. On LENR-active substrate surfaces, there are a myriad of different complex, nanometer-to micron-scale electromagnetic, chemical, and nuclear processes that can and do operate in conjunction with and in parallel with each other. LENRs involve interactions between surface plasmon electrons, E-M fields, and many different types of nanostructures with varied geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical/isotopic compositions; chemical and nuclear realms interoperate

- To varying degrees, many of these complex, time-varying surface interactions are electromagnetically coupled on many different physical length-scales: thus, E-M resonances can be very important in such systems. To wit, in addition to optical frequencies, SPs in condensed matter often also have some absorption and emission bands located in infrared (IR) portion of E-M spectrum. Well, walls of gas-phase metallic LENR reaction vessels intrinsically have SPs present on their inner surfaces and can thus radiate IR E-M energy into the interior space; vessels function as resonant E-M cavities. 'Target' nanostructures/nanoparticles/molecules located inside such vessels can absorb IR radiated from vessel walls if their absorption bands happen (or are engineered) to fall into same spectral range as IR cavity wall radiation emission; complex two-way E-M interactions between 'targets' and walls occurs (imagine the interior of a reaction vessel as huge arrays of IR nanoantennas with walls and 'targets' having complementary two-way send/receive channels)

- Please be aware that a wide variety of complex, interrelated E-M, nuclear, and chemical processes may be occurring simultaneously side-by-side in adjacent *nm* to *μ*-scale local regions on a given surface. For example, some regions on a surface may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At same time, energy can be transferred laterally from regions of resonant absorption or 'capture' to other regions in which emission or 'consumption' is taking place: e.g., photon or electron emission, and/or LENRs in which [E-M field energy] + $e^- \rightarrow e^{-*} + p^+ \rightarrow n_{ulm} + \nu$

- In LENRs, electrons and protons (charged particles) are truly 'consumed' (i.e., cease to exist as individual particles) by virtue of being converted into uncharged neutrons via weak reactions; LENR-produced new elements can then engage in varied chemical reactions

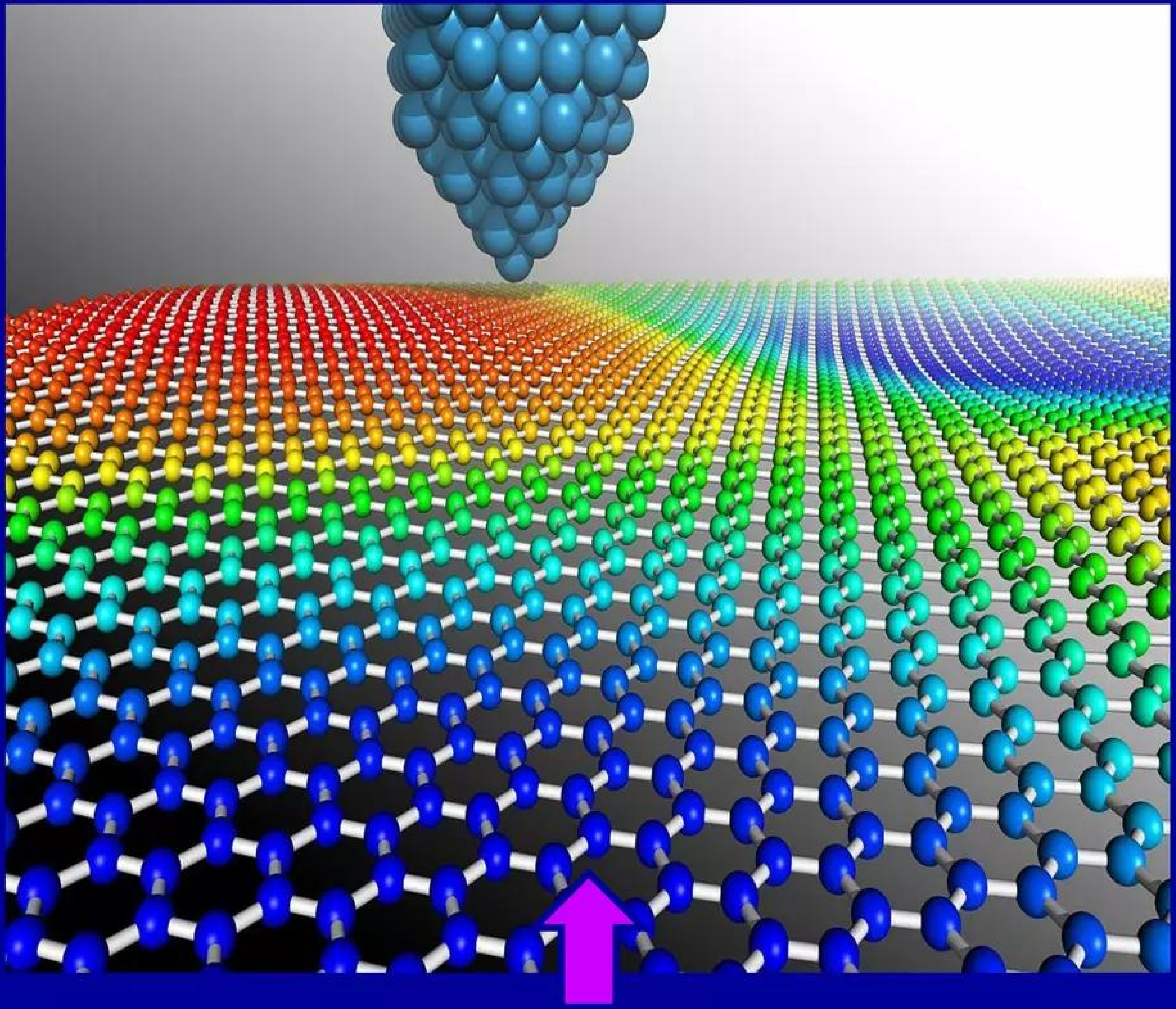
- Conclusions: working in concert with many-body, collective Q-M effects, SP electrons also function as two-way energy 'transducers', thus effectively interconnecting otherwise normally rather distant realms of chemical and nuclear energy scales in condensed matter. Technical knowledge in nanotechnology, materials science, plasmonics, fullerene/graphene chemistry, and proprietary aspects of WLT can be integrated, applied, and utilized to design and engineer LENR-active nanostructured surfaces for commercial applications



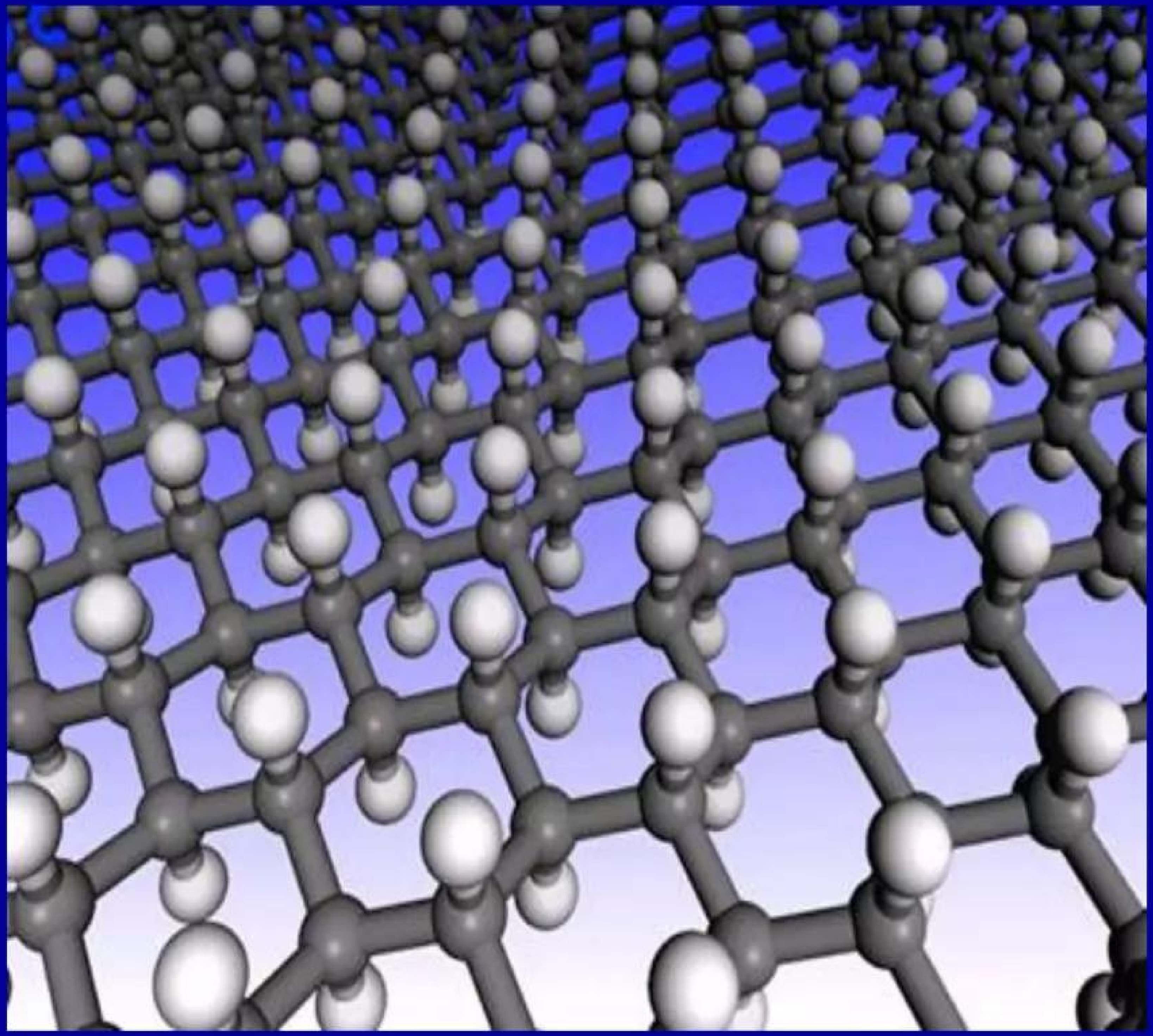
Selected background technical information about Graphene, Graphane, aromatic molecular structures, nanoantennas, and resonant E-M fields around nanoparticles

LENRs and Carbon chemistry intermingle on nanoscales

Graphene: Carbon atoms are multicolored (no bound Hydrogen)



Graphane: Carbon atoms in gray, hydrogen atoms in white



Graphene - Calvin Davidson, Sussex University - see URL = http://www.britishcarbon.org/images.shtml

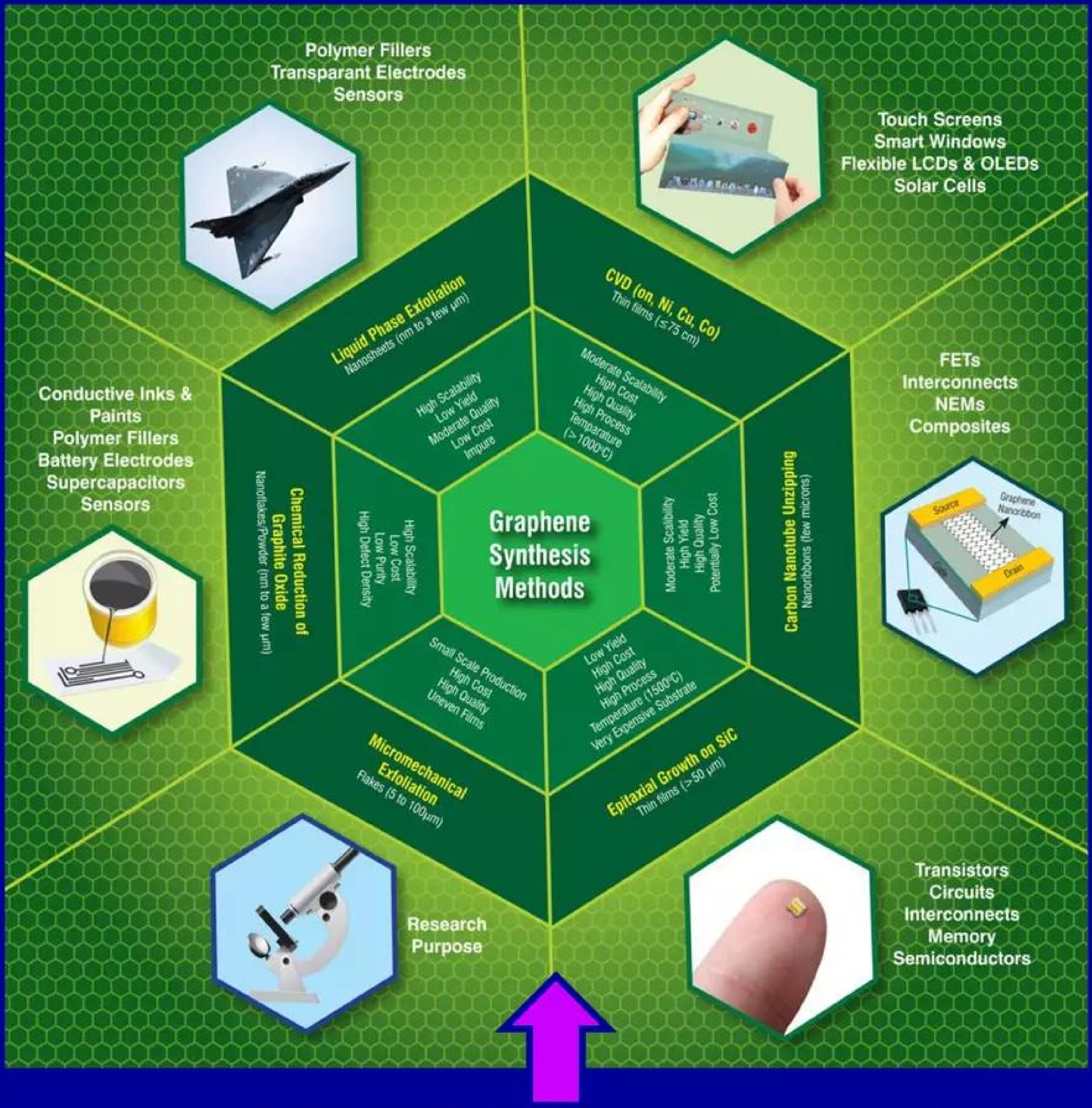
In July 2008, Levente Tapasztó *et al*[1] reported their ability to etch graphene nanoribbons using a scanning tunneling microscope to produce almost atomically precise structures and predetermined electronic properties. This image shows a tungsten [100] scanning tunneling microscope tip approaching a stylized sheet of perfect graphene, undulating with a wavelength of 8 nm, as predicted by Fasolino *et al*[2] in 2007.

1 Tapaszto *et al*., "*Tailoring the atomic structure of graphene nanoribbons by scanning tunneling microscope lithography*," *Nat Nanotech* 3 (7) pp. 397 - 401 (2008)
2 Fasolino *et al*., "*Intrinsic ripples in graphene*," *Nature Materials* 6 pp. 858 - 861 (2007)

Graphene produced during arc discharge and pyrolysis

Mass spectroscopy reveals that LENRs may occur during these processes

"*Mass production of high quality graphene: An analysis of worldwide patents*" *Nanowerk Spotlight* June 28, 2012



***"Arc Discharge Method for the Large-Scale Low-cost Production of Graphene Nanosheets: a**mong the various chemical methods available for the synthesis of graphene, arc-discharge bottom-up method shows significant potential for the large-scale production of few-layered high-quality graphene nanosheets (US20110114499A, CN101993060, CN102153076). The graphene can be synthesized by direct current arc-discharge evaporation of pure graphite electrodes in a variety of gases, including H_2, NH_3, He, Ar, CO_2 and their mixtures as well as air. The process has many advantages: the synthesized graphene is of high purity and highly crystalline in nature; it also exhibits high crystallinity and high oxidation resistance; the resulting graphene sheets can be well-dispersed in organic solvents, therefore they are quite suitable for the solution processing of flexible and conductive films; arc-discharge synthesis can also be used to synthesize graphene doped with nitrogen (CN101717083A). It is feasible to synthesize good quality graphene sheets from graphite oxide also, and the synthesized graphene shows superior electrical conductivity and high temperature stability as compared to thermally exfoliated graphene."

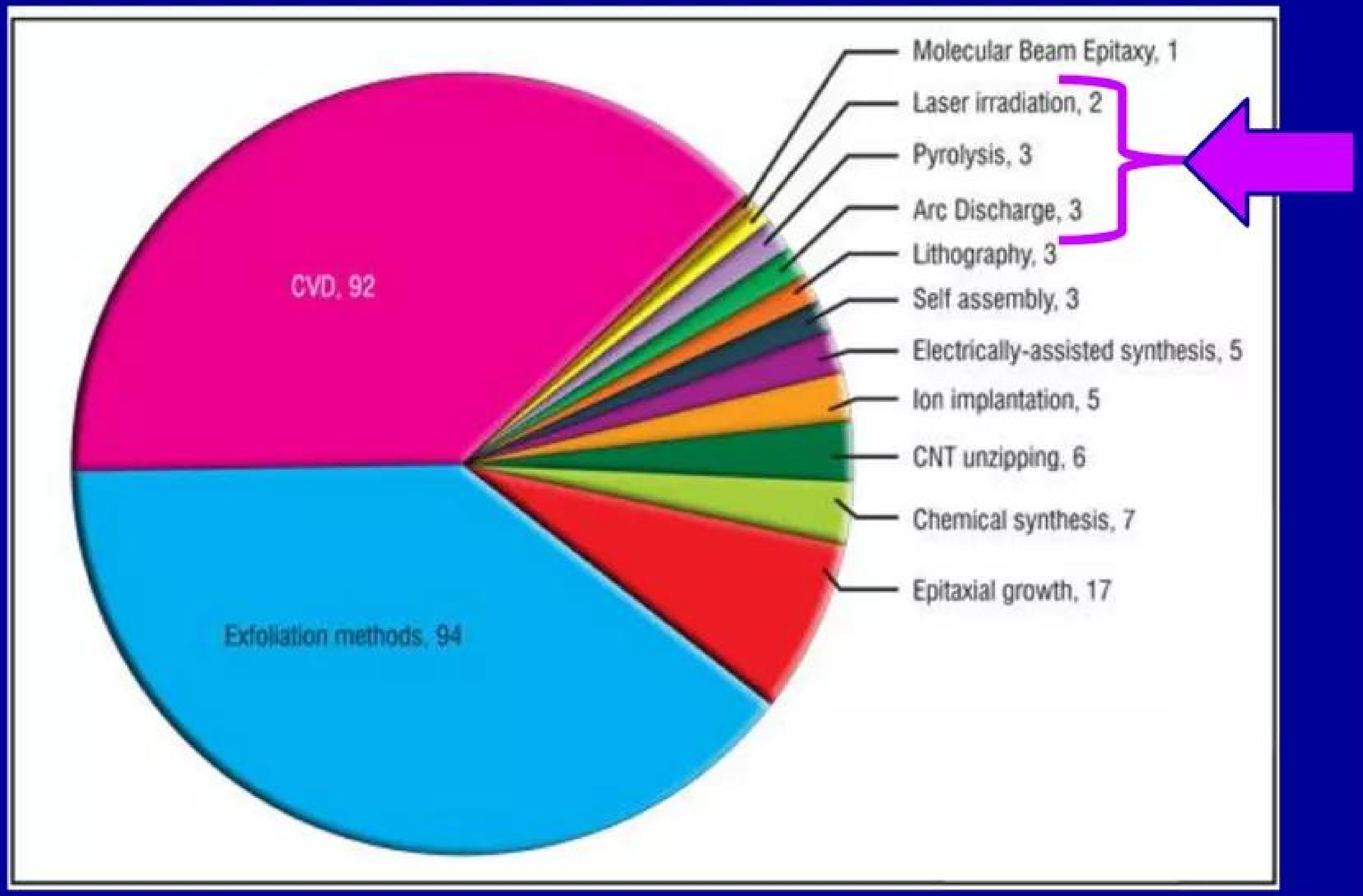


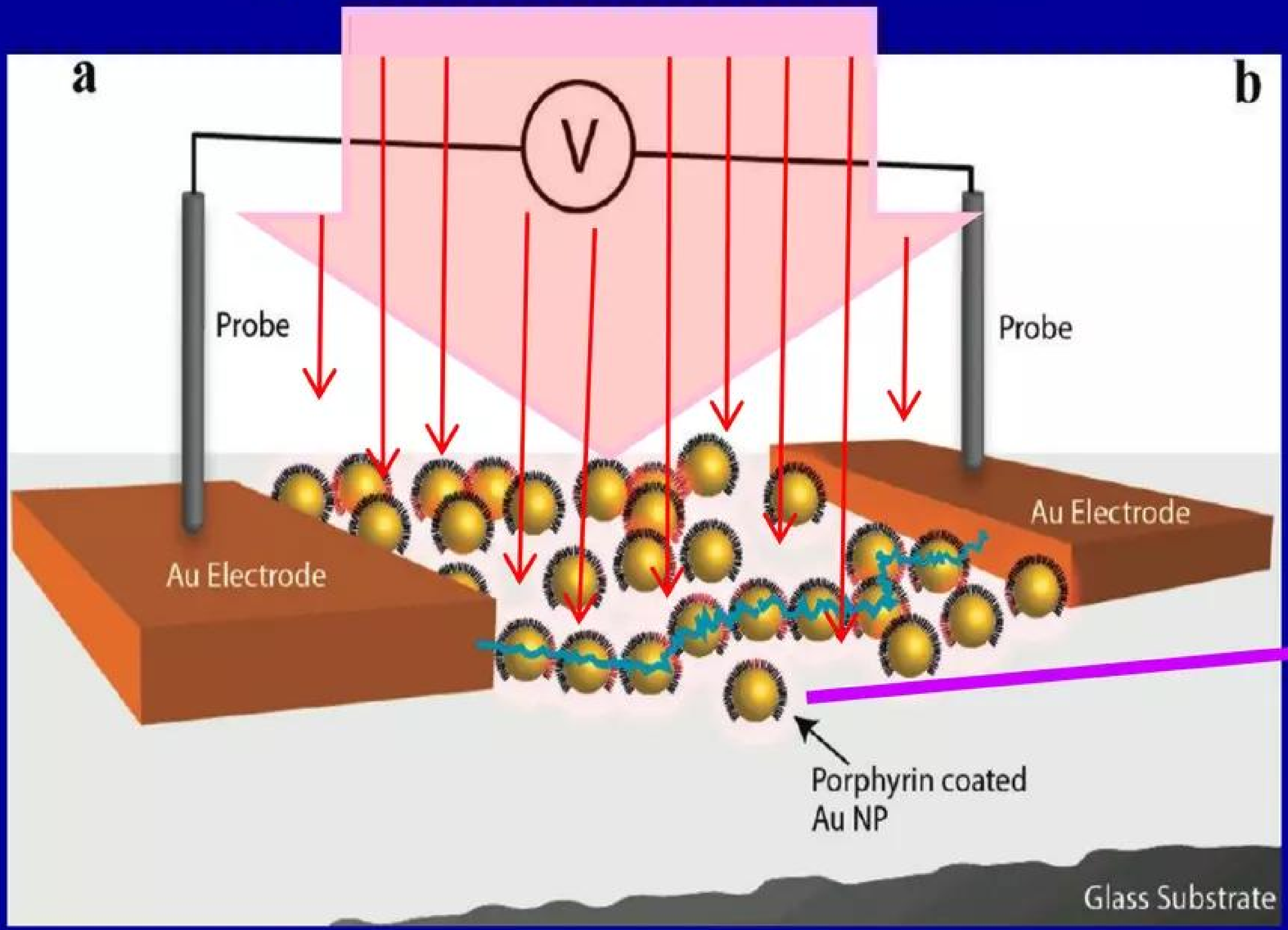
Image credit: CKMNT see URL = http://www.nanowerk.com/spotlight/spotid=25744.php

Resonant E-M fields couple C-rings and surface plasmons

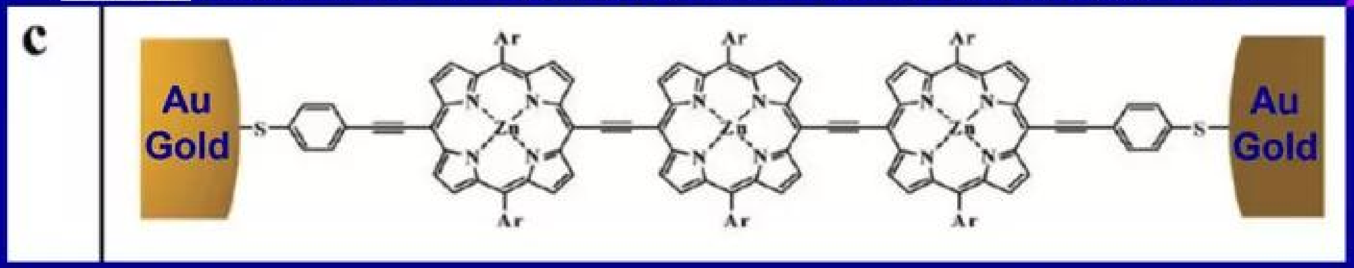
Show focusing + transduction of optical radiation to current in molecular circuit

Images and captions adapted from: "*Plasmon-Induced Electrical Conduction in Molecular Devices*," P. Banerjee *et al.*, *ACS Nano* 4 (2), pp. 1019 - 1025 (2010)
DOI: 10.1021/nn901148m
http://pubs.acs.org/doi/abs/10.1021/nn901148m

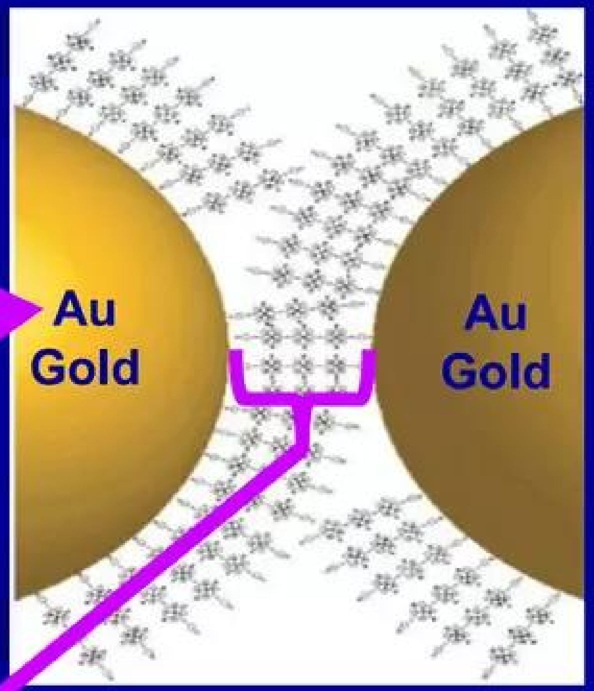
Input energy = E-M photons emitted from laser



Below: details of 'molecular wire' circuit between Au NPs



Example of Porphyrin Carbon rings coordinating Fe atom



Short chains of linked Porphyrin molecules serve as 'bridge wires' between surfaces of adjacent metallic Au nanoparticles

Quoting directly from their abstract:

"Metal nanoparticles (NPs) respond to electromagnetic waves by creating surface plasmons (SPs), which are localized, collective oscillations of conduction electrons on the NP surface. When interparticle distances are small, SPs generated in neighboring NPs can couple to one another, creating intense fields. The coupled particles can then act as optical antennae capturing and refocusing light between them. Furthermore, a molecule linking such NPs can be affected by these interactions as well. Here, we show that by using an appropriate, highly conjugated multiporphyrin chromophoric wire to couple gold NP arrays, plasmons can be used to control electrical properties. In particular, we demonstrate that the magnitude of the observed photoconductivity of covalently interconnected plasmon-coupled NPs can be tuned independently of the optical characteristics of the molecule - a result that has significant implications for future nanoscale optoelectronic devices."

Free copy of entire paper at http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/4102/274635800055.pdf?sequence=1

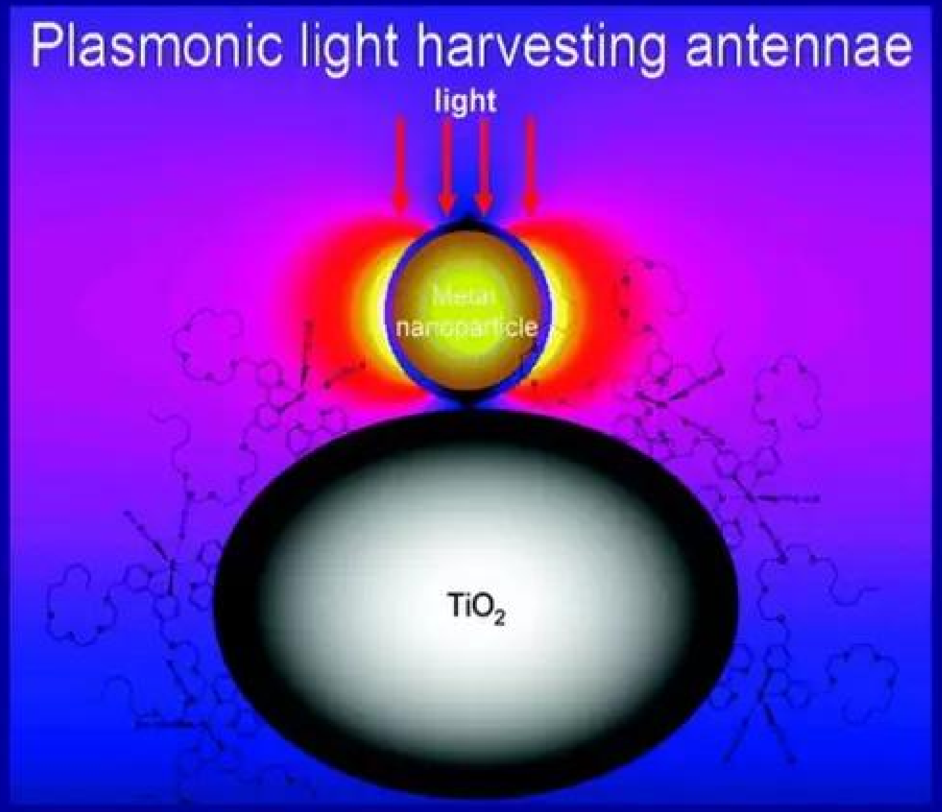
Large E-field enhancements near nanoparticles on surfaces

Antenna-like resonant absorption and emission of electromagnetic field energy

- ✓ **Pucci *et al.* (2008): "If metal structures are exposed to electromagnetic radiation, modes of collective charge carrier motion, called plasmons, can be excited … Surface plasmons can propagate along a distance of several tens of micrometers on the surface of a film."**
- ✓ **"In the case of one nanoparticle, the surface plasmon is confined to the three dimensions of the nanostructure and it is then called localized surface plasmon (LSP). In this situation, the LSP resonance depends on the metallic nature (effect of the metal permittivity) and on the geometry (effect of the confinement of the electron cloud) of the nanostructure."**
- ✓ **"If the smallest dimension of the particle is much larger than the skin depth of the electromagnetic radiation in the metal, also real metal wires can be estimated as perfect conductors. For ideal metal objects it is assumed that the light does not penetrate into the particle. This means an infinitely large negative dielectric function. Then, antenna-like resonances occur if the length L of an infinitely thin wire matches with multiples of the wavelength λ."**
- ✓ **"Electromagnetic scattering of perfect conducting antennas with D smaller than the wavelength and L in the range of the wavelength is discussed in classical antenna scattering theory … It is a frequently used approximation to consider a metal nanowire as an ideal antenna. This approach has been proposed also for the modeling of nanowires in the visible spectral range …"**
- ✓ **"… field is enhanced at the tip of the nanowire when the excitation wavelength corresponds to an antenna mode … the end of the nanowires in a relatively sharp and abrupt surface is a perfect candidate to host a lightning rod effect ..." [N.B. - huge localized E-fields created near sharp tips]**
- ✓ **"… for metallic wires larger than several hundred nanometers. The increasing size of the nanoantennas makes the resonances to appear at wavelengths that present larger negative values of the dielectric function, i.e. for wavelengths well in the mid infrared portion of the spectrum in the case of micron-sized wires. It is actually this extension of the resonant behavior to micron-sized antennas what makes these structures optimal candidates for surface enhanced Raman spectroscopy (SERS) and surface-enhanced infrared absorption spectroscopy (SEIRA)."**

Reference for Pucci *et al.*:

***"Electromagnetic nanowire resonances for field-enhanced spectroscopy,"* Chap. 8 in *"One-Dimensional Nanostructures,"* Pucci *et al.*, Series: Lecture Notes in Nanoscale Science and Technology, V. 3, Wang, Zhiming M. (Ed.), Springer pp. 178-181 (2008)**

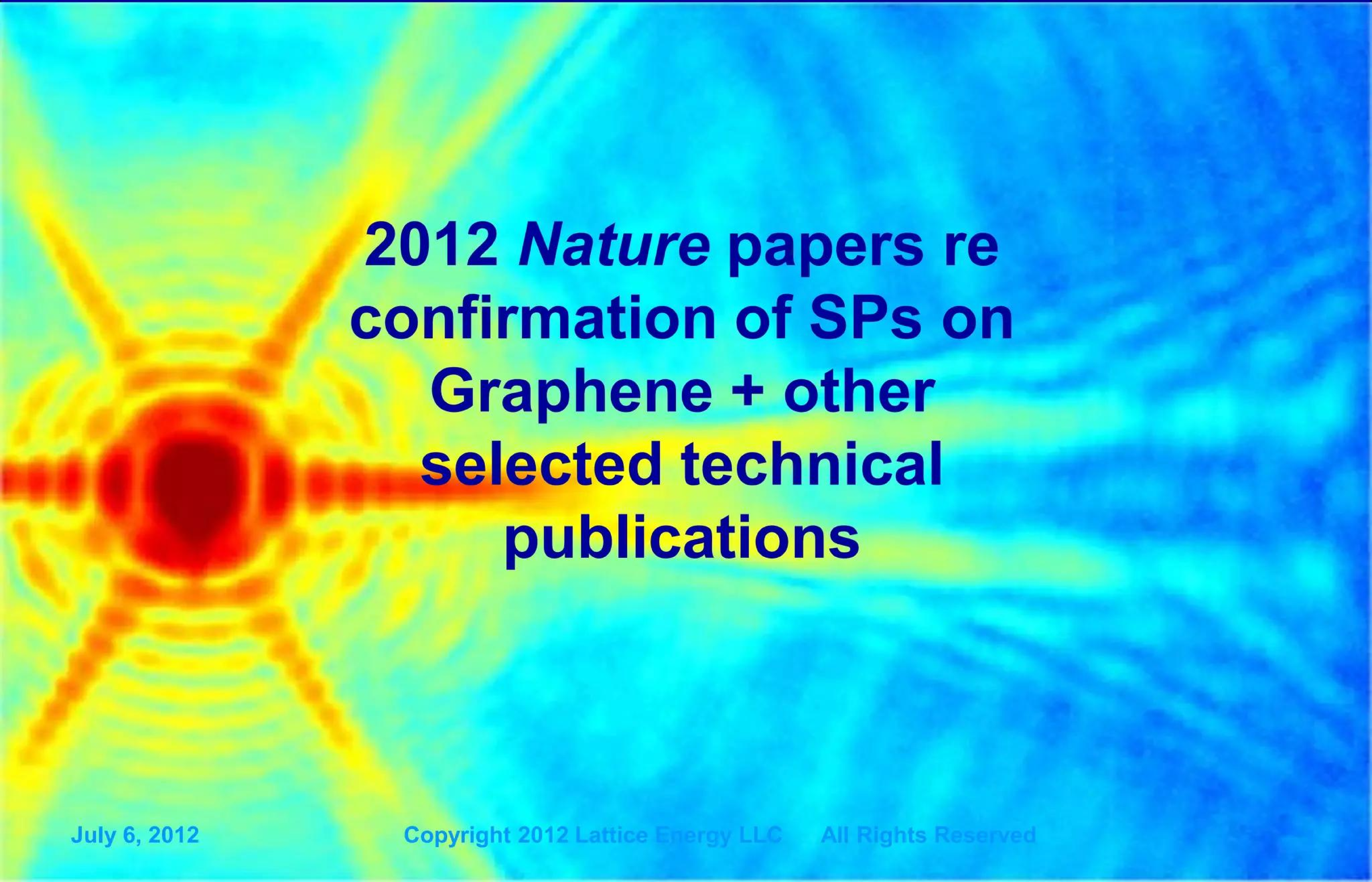


http://people.ccmr.cornell.edu/~uli/res_optics.htm

Source of above image is the Wiesner Group at Cornell University:

See: "*Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles*," M. Brown *et al.*, *Nano Letters* 11 (2) pp. 438 - 445 (2011)

http://pubs.acs.org/doi/abs/10.1021/nl1031106



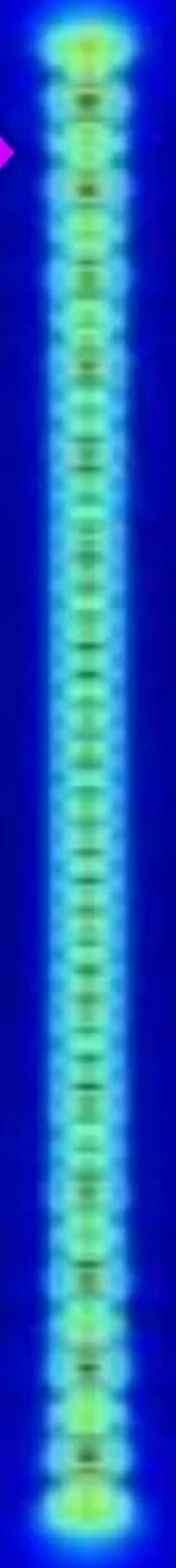
2012 *Nature* papers re confirmation of SPs on Graphene + other selected technical publications

J. Chen *et al*. (2012) confirm surface plasmons on Graphene

" ... Turn a graphene nanostructure into a tunable resonant plasmonic cavity"

"*Optical nano-imaging of gate-tunable graphene plasmons*"
J. Chen *et al*.
***Nature* doi:10.1038/nature11254 published online 20 June (2012)**
http://www.nature.com/nature/journal/vaop/ncurrent/full/nature11254.html
Free preprint: http://arxiv.org/ftp/arxiv/papers/1202/1202.4993.pdf

Computer simulation of 1-dimensional cavity wave shown to right (unrelated to this paper)



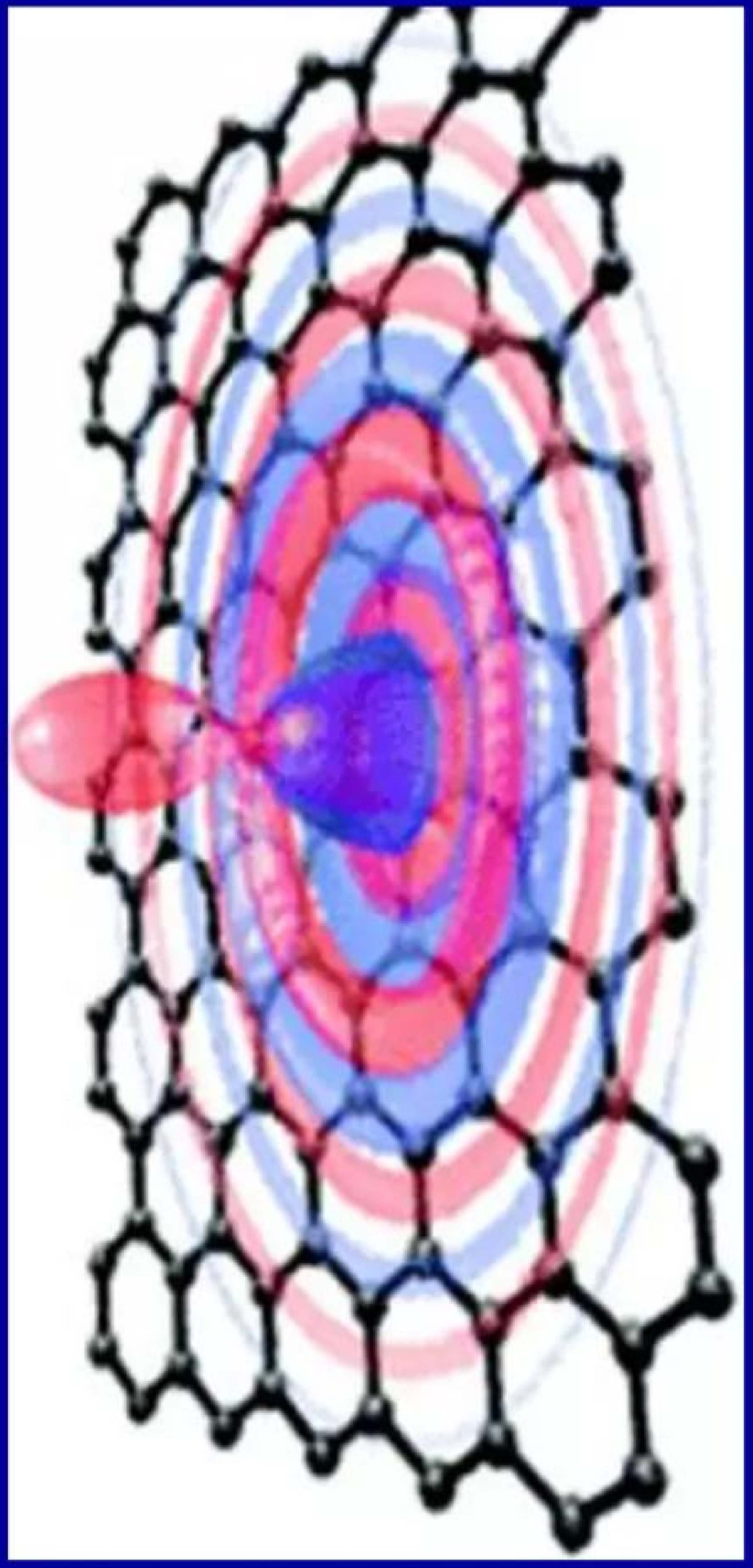
Abstract: "The ability to manipulate optical fields and the energy flow of light is central to modern information and communication technologies, as well as quantum information processing schemes. However, as photons do not possess charge, controlling them efficiently by electrical means has so far proved elusive. A promising way to achieve electric control of light could be through plasmon polaritons - coupled excitations of photons and charge carriers - in graphene. In this two-dimensional sheet of carbon atoms, it is expected that plasmon polaritons and their associated optical fields can be readily tuned electrically by varying the graphene carrier density. While optical graphene plasmon resonances have recently been investigated spectroscopically, no experiments so far have directly resolved propagating plasmons in real space. Here, we launch and detect propagating optical plasmons in tapered graphene nanostructures using near-field scattering microscopy with infrared excitation light. We provide real-space images of plasmonic field profiles and find that the extracted plasmon wavelength is remarkably short - over 40 times smaller than the wavelength of illumination. We exploit this strong optical field confinement to turn a graphene nanostructure into a tunable resonant plasmonic cavity with extremely small mode volume. The cavity resonance is controlled *in-situ* by gating the graphene, and in particular, complete switching on and off of the plasmon modes is demonstrated, thus paving the way towards graphene-based optical transistors. This successful alliance between nanoelectronics and nano-optics enables the development of unprecedented active subwavelength-scale optics and a plethora of novel nano-optoelectronic devices and functionalities, such as tunable metamaterials, nanoscale optical processing and strongly enhanced light-matter interactions for quantum devices and (bio) sensing applications."

Z. Fei *et al*. (2012) confirm surface plasmons on Graphene

"Show that common graphene ... structures support ... surface plasmons"

"*Gate-tuning of graphene plasmons revealed by infrared nano-imaging*"
Z. Fei *et al*.
***Nature* doi:10.1038/nature11253 published online 20 June (2012)**
http://www.nature.com/nature/journal/vaop/ncurrent/full/nature11253.html?WT.ec_id=NATURE-20120621
Free preprint: http://arxiv.org/ftp/arxiv/papers/1202/1202.4993.pdf

Abstract: "Surface plasmons are collective oscillations of electrons in metals or semiconductors enabling confinement and control of electromagnetic energy at subwavelength scales. Rapid progress in plasmonics has largely relied on advances in device nano-fabrication, whereas less attention has been paid to the tunable properties of plasmonic media. One such medium --- graphene --- is amenable to convenient tuning of its electronic and optical properties with gate voltage. Through infrared nanoimaging we explicitly show that common graphene/SiO$_2$/Si back-gated structures support propagating surface plasmons. The wavelength of graphene plasmons is of the order of 200 nm at technologically relevant infrared frequencies, and they can propagate several times this distance. We have succeeded in altering both the amplitude and wavelength of these plasmons by gate voltage. We investigated losses in graphene using plasmon interferometry: by exploring real space profiles of plasmon standing waves formed between the tip of our nano-probe and edges of the samples. Plasmon dissipation quantified through this analysis is linked to the exotic electrodynamics of graphene. Standard plasmonic figures of merits of our tunable graphene devices surpass that of common metal-based structures."



Graphic image: concept of a Graphene plasmon dipole emitter (unrelated to *Nature* paper)

Breakdown of the Born-Oppenheimer approximation

Experimentally confirmed in Graphene (2007) and Carbon nanotubes (2009)

"*Breakdown of the adiabatic Born-Oppenheimer approximation in graphene*"
S. Pisana *et al.*
***Nature Materials* 6 pp. 198 - 201 (2007)**
http://www.condmat.physics.manchester.ac.uk/pdf/mesoscopic/publications/graphene/Naturemat_2007Raman.pdf

Abstract: "The adiabatic Born-Oppenheimer approximation (ABO) has been the standard *ansatz* to describe the interaction between electrons and nuclei since the early days of quantum mechanics. ABO assumes that the lighter electrons adjust adiabatically to the motion of the heavier nuclei, remaining at any time in their instantaneous ground state. ABO is well justified when the energy gap between ground and excited electronic states is larger than the energy scale of the nuclear motion. In metals, the gap is zero and phenomena beyond ABO (such as phonon-mediated superconductivity or phonon induced renormalization of the electronic properties) occur. The use of ABO to describe lattice motion in metals is, therefore, questionable. In spite of this, ABO has proved effective for the accurate determination of chemical reactions, molecular dynamics, and phonon frequencies in a wide range of metallic systems. Here, we show that ABO fails in graphene. Graphene, recently discovered in the free state is a zero band gap semiconductor that becomes a metal if the Fermi energy is tuned applying a gate voltage, Vg. This induces a stiffening of the Raman G peak that cannot be described within ABO."

"*Breakdown of the adiabatic Born-Oppenheimer approximation in graphene*"
A. Bushmaker *et al.*
***Nano Letters* 9 pp. 607 - 611 (2009)**
http://authors.library.caltech.edu/14403/1/Bushmaker2009p17610.1021nl802854x.pdf

Abstract: "Raman spectra and electrical conductance of individual, pristine, suspended, metallic single-walled carbon nanotubes are measured under applied gate potentials. The G-band is observed to downshift with small applied gate voltages, with the minima occurring at $E_F = \pm \frac{1}{2} E_{phonon}$, contrary to adiabatic predictions. A subsequent upshift in the Raman frequency at higher gate voltages results in a "W"-shaped Raman shift profile that agrees well with a nonadiabatic phonon renormalization model. This behavior constitutes the first experimental confirmation of the theoretically predicted breakdown of the Born-Oppenheimer approximation in individual single-walled carbon nanotubes."

Quoting from body of paper: "Although the BO approximation is valid in most materials and molecular systems, there are a few situations in which it does not hold, including some low atomic weight compounds, intercalated graphite, and graphene ... In nanotubes, the BO approximation is expected to break down because of the relatively short vibrational period of the longitudinal optical (LO) phonon and the relatively long electronic relaxation time."

Examples: methods of synthesis for Carbon nanotubes

High-current electric arcs in different apparatus produce copious CNTs

"*Synthesis of branched Carbon nanotubes from coal*"
Z. Wang *et al.*
Carbon 44 pp. 1298 - 1352 (2006)
http://finechem.dlut.edu.cn/carbon/eng/pdf/2006-8.pdf

Quoting from body of paper: "In comparison to other methods available now, the arc-discharge approach is still widely used because of its simplicity and convenience in operation and the capability of producing tubes with well-developed graphene-based structures. Here we report the synthesis of BCNTs from coal, the cheapest natural carbon source, by arc-discharge with copper as catalyst. It has been found that BCNTs with a purity of ca. 70% can be obtained in large quantity under suitable experimental conditions. The preparation experiments were carried out in helium in a traditional DC arc-discharge reactor. The anode was a high-purity graphite tube (10 mm outside diameter, 8 mm inside diameter and 150 mm in length) filled with a mixture of anthracite coal (from Yunnan Province, China) and CuO powder (smaller than 150 lm in size) while the cathode was a high purity graphite rod (15 mm outside diameter, 30 mm in length) ... Right now the detailed mechanism involved in the formation of BCNTs is not clear ... coal must play a critical role in this process simply because few BCNTs were obtained in similar tests using high-purity graphite powder as carbon source instead of coal powder. It is known that coal is a macromolecular solid consisting of abundant irregular polymerized aromatic hydrocarbon units that are joined together by weak cross-links. During the fast pyrolysis process in arc plasma, these weak cross-links would be readily broken up, releasing great quantities of reactive hydrocarbon molecules, i.e. polycyclic hydrocarbons could be a secondary product formed from the arc process.."

United States Patent US #7,816,619 B2
"METHODS AND APPARATUS FOR MANUFACTURING CARBON NANOTUBES"
N. Jaksic - Inventor and Assignee
Date of Patent: October 19, 2010
http://www.freepatentsonline.com/7816619.pdf

Abstract: "A process for manufacturing carbon nanotubes, including a step of creating an electric arc in an electric field between a carbonaceous anode and a carbonaceous cathode under conditions effective to produce the carbon nanotubes, wherein the carbonaceous anode and the carbonaceous cathode are immersed in dielectric liquid serving as a dielectric, coolant and for providing an oxygen-free environment. Preferably, one of the electric discharge machining dielectric oils is used as dielectric liquid. Preferably, an electric discharge machine is used to immerse the electrodes in the dielectric liquid, create an electric field, induce the arc, and adjust the gap between the electrodes thus optimizing the yield of carbon nanotubes. The process is cost-effective, easy to implement, and provides high-quality carbon nanotubes while eliminating the need for dedicated equipment and catalysts."

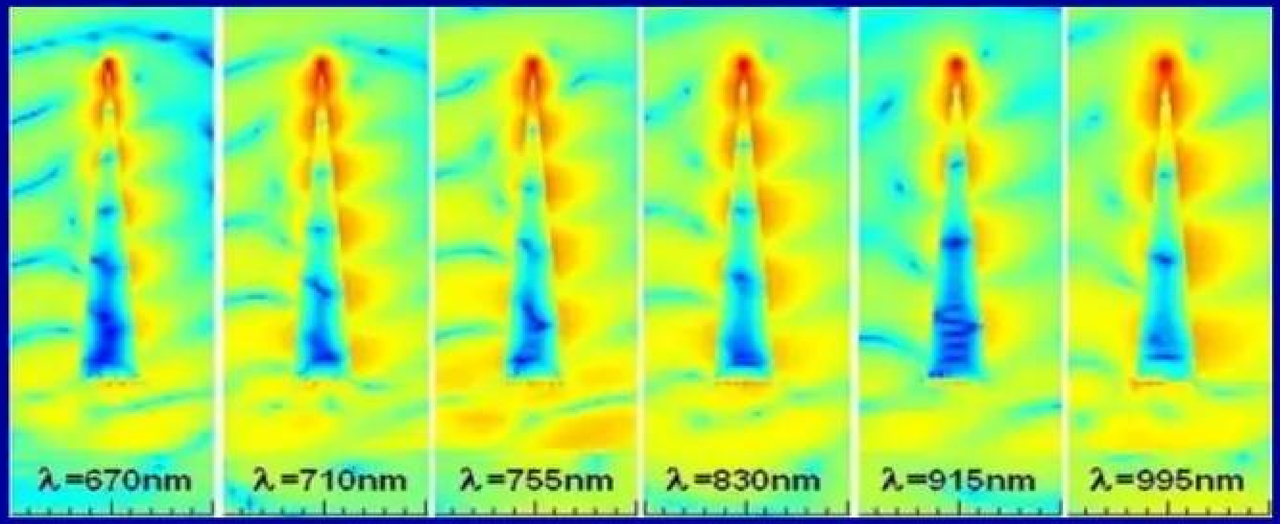
N.B. - one alternative "dielectric liquid" as described in patent specification is Rustlick EDM-500 transformer oil; see H. Nagaoka, *Nature* 1925 where likely made Gold from Tungsten via WLT LENR transmutation process

Examples: methods of synthesis for Graphene

Arc-discharges make Graphene; likely produced during 1994 experiments

"Low-cost and large-scale synthesis of Graphene by arc discharge in air"
Z. Wang *et al.*
Nanotechnology 21 pp. 175602 (2010)
http://iopscience.iop.org/0957-4484/21/17/175602

Abstract: "Large scale production of graphene nanosheets was achieved by arc evaporation of a graphite rod in air. The graphene nanosheets are ~ 100 - 200 *nm* wide and the number of layers is mainly in the range of 2 - 10. Several tens of grams of product were obtained per day. The yield of graphene nanosheets was found to be dependent on the pressure of the air, i.e. high pressure facilitates the formation of graphene nanosheets, but low pressure favors the growth of other carbon nanostructures including carbon nanohorns and nanospheres. Based on this result, a pressure-induced mechanism of formation of graphene nanosheets is proposed. The impurities in the products could be eliminated by oxidation in air."



"A brief review of Graphene-based material synthesis and its application in environmental pollution management"
L. Kui *et al.*
Materials Science 57 pp. 1223 - 1234 (2012)
http://www.springerlink.com/content/7514660519659838/fulltext.pdf

Abstract: "Graphene is an interesting two-dimensional carbon allotrope that has attracted considerable research interest because of its unique structure and physicochemical properties. Studies have been conducted on graphene-based nanomaterials including modified graphene, graphene/semiconductor hybrids, graphene/metal nanoparticle composites, and graphene-complex oxide composites. These nanomaterials inherit the unique properties of graphene, and the addition of functional groups or the nanoparticle composites on their surfaces improves their performance. Applications of these materials in pollutant removal and environmental remediation have been explored. From the viewpoint of environmental chemistry and materials, this paper reviews recent important advances in synthesis of graphene-related materials and their application in treatment of environmental pollution. The roles of graphene-based materials in pollutant removal and potential research are discussed."

Examples: methods of synthesis for Graphane

H_2 molecule unreactive w. Graphene; need atomic Hydrogen to make Graphane

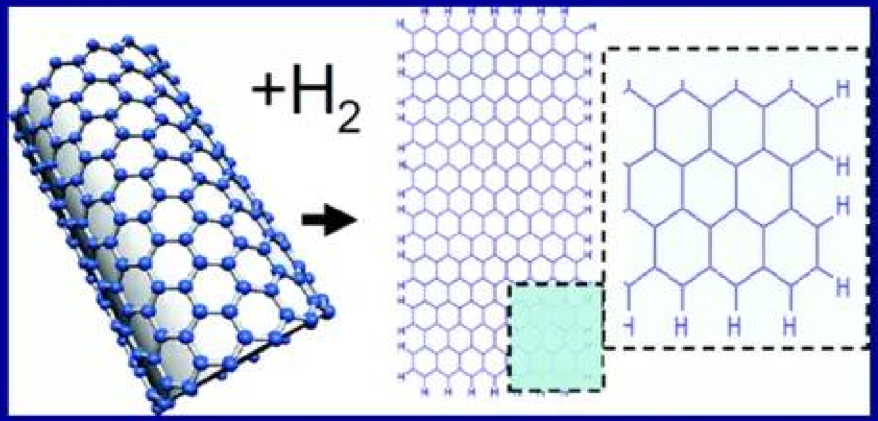
"*Graphene to Graphane: novel electrochemical conversion*"
K. Daniels *et al.*
Cornell arXiv preprint (October 26, 2010)
http://arxiv.org/ftp/arxiv/papers/1010/1010.5458.pdf

Abstract: "A novel electrochemical means to generate atomic hydrogen, simplifying the synthesis and controllability of graphane formation on graphene is presented. High quality, vacuum grown epitaxial graphene (EG) was used as starting material for graphane conversion. A home-built electrochemical cell with Pt wire and exposed graphene as the anode and cathode, respectively, was used to attract H+ ions to react with the exposed graphene. Cyclic voltammetry of the cell revealed the potential of the conversion reaction as well as oxidation and reduction peaks, suggesting the possibility of electrochemically reversible hydrogenation. A sharp increase in D peak in the Raman spectra of EG, increase of D/G ratio, introduction of a peak at ~2930 cm$_{-1}$ and respective peak shifts as well as a sharp increase in resistance showed the successful hydrogenation of EG. This conversion was distinguished from lattice damage by thermal reversal back to graphene at 1000°C."

Quoting from body of paper: "... Graphane is as thermodynamically stable as comparable hydrocarbons, more stable than metal hydrides and more stable than Graphene by ~0.15 eV. This along with its large hydrogen storage capacity 7.7 wt%, which exceeds the Department of Energy (DOE) 2010 target of 6% also makes it a promising candidate for hydrogen storage."

"*Hydrogenation, purification, and unzipping of Carbon nanotubes by reaction with molecular Hydrogen: road to Graphane nanoribbons*"
A. Talyzin *et al.*
ACSNano 5 pp. 5132 - 5140 (2011)
http://pubs.acs.org/doi/abs/10.1021/nn201224k

Abstract: "Reaction of single-walled carbon nanotubes (SWNTs) with hydrogen gas was studied in a temperature interval of 400 - 550°C and at hydrogen pressure of 50 bar. Hydrogenation of nanotubes was observed for samples treated at 400 - 450°C with about 1/3 of carbon atoms forming covalent C–H bonds, whereas hydrogen treatment at higher temperatures (550°C) occurs as an etching. Unzipping of some SWNTs into graphene nanoribbons is observed as a result of hydrogenation at 400 - 550°C. Annealing in hydrogen gas at elevated conditions for prolonged periods of time (72 h) is demonstrated to result also in nanotube opening, purification of nanotubes from amorphous carbon, and removal of carbon coatings from Fe catalyst particles, which allows their complete elimination by acid treatment."

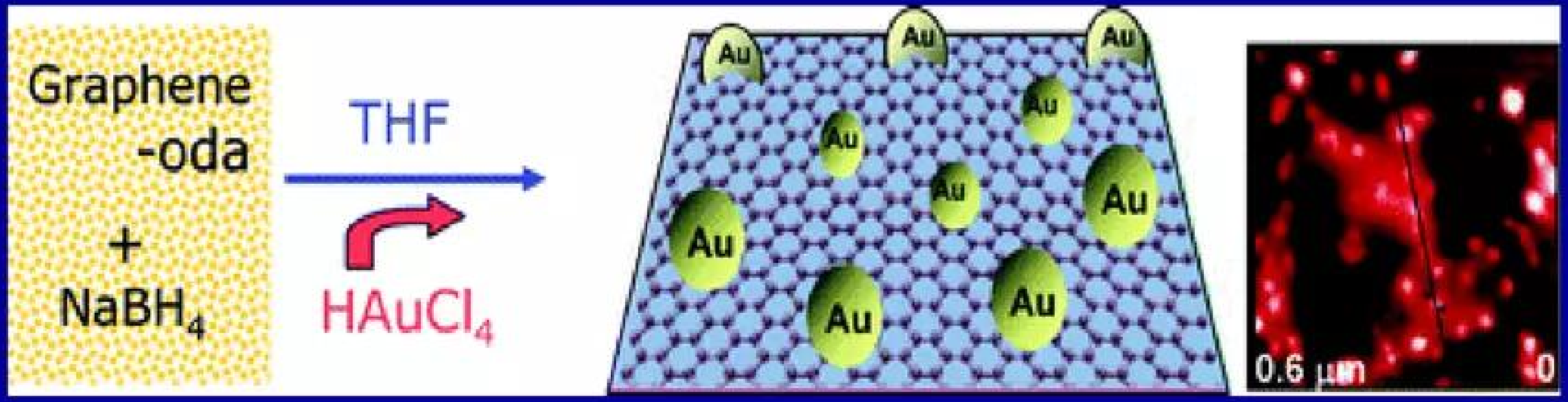


Metallic nanoparticles on CNTs and Graphene surfaces

WLT LENR-active devices could use fabricated nanoparticles on surfaces

"*Decorating Graphene sheets with Gold Nanoparticles*"
R. Muszynski *et al.*
***Journal of Physical Chemistry C* 112 pp. 5263 - 5266 (2008)**
http://files.instrument.com.cn/FilesCenter/20101218/Decorating%20Graphene%20Sheets%20with%20Gold%20Nanoparticles.pdf

Abstract: "Renewed interest in graphene architectures has opened up new avenues to utilize them in electronic and optoelectronic applications. The desire to design graphene−metal nanohybrid assemblies has led us to explore a solution-based approach of chemical reduction of $AuCl_4^-$ ions in graphene suspensions. The gold particles anchored on octadecylamine functionalized graphene are readily suspendable in THF medium. The dependence of particle stability on the graphene concentration and SEM analysis indicate that the gold nanoparticles are well dispersed on graphene sheets. Transient absorption spectroscopy measurements suggest that the ultrafast disappearance of plasmon absorption and its recovery are unaffected by the presence of graphene."



"*Preparation of Ag-Fe-decorated single-walled Carbon nanotubes by arc discharge and their antibacterial effect*"
X. Liu *et al.*
***Journal of Materials Science* 47 pp. 6086 - 6094 (2012)**
http://www.springerlink.com/content/u97g45m817373066/

Abstract: "A simple one-step approach for the preparation of Ag-Fe-decorated single-walled carbon nanotubes (Ag-Fe/SWCNTs) by DC hydrogen arc discharge is presented in this article. The growth of SWCNTs and the attachment of Ag and Fe nanoparticles to the SWCNTs occur simultaneously during the arc discharge evaporation process. It has been confirmed that the Ag and Fe nanoparticles in the diameter range of 1-10 *nm* are well dispersed and tightly attached to the outer surfaces of SWCNTs. The as-grown Ag-Fe/SWCNTs have been purified by high-temperature hydrogen treatment to remove amorphous carbon and carbon shells. Antibacterial tests show that the antibacterial activity of the purified Ag-Fe/SWCNT hybrid nanoparticles is excellent against *Escherichia coli*. The percentage of the *E. coli* killed by 100 *μg/ml* Ag-Fe/SWCNTs can reach up to 85.1% at a short residence time of 2 h, suggesting that the purified Ag-Fe/SWCNTs may have potential antibacterial applications."

Arc discharges in liquids fabricate metallic nanoparticles

Conceptually akin to 1994 Carbon-arc LENR experiments and US #7,816,619 B2

"*Development of pressure control technique of an arc-submerged nanoparticle synthesis system (ASNSS) for Copper nanoparticle production*"
T. Tsung *et al.*
Materials Transactions 44 pp. 1138 - 1142 (2003)
http://www.jim.or.jp/journal/e/pdf3/44/06/1138.pdf

Abstract: "The synthesis of nano-materials is one of the crucial techniques towards product and process innovation. In this article, low-pressure control methods for an arc-submerged nanoparticle synthesis system (ASNSS) was proposed and developed for copper nanoparticle fabrication. Two technical advances associated with nanoparticle synthesis were achieved. One is the novel pressure control technique developed for nanoparticle fabrication. The other is the verification that the constant low-operating pressure plays an important role in determining the characteristics of the prepared nanoparticles. From the experimental results, pressure control of the ASNSS was identified as crucial to success of metal nanoparticle synthesis. To achieve the desired pressure control, a vacuum chamber was developed as a nanoparticle accumulator and low pressure reservoir. The chamber was controlled by the proposed flow-valve feedback control system and integrated with the ASNSS. In this study, the pressure control equipment of the ASNSS was effectively developed to prepare desired copper nanocrystalline particles with well controlled size."

Selected excerpts from body of the paper: "The dielectric liquid in the vacuum chamber is deionized water ... In addition, the dielectric liquid is vaporized by part of the submerged arc rapidly while the metal electrodes are heated ... The cuprum nanoparticle preparation is described below. A Cu bulk bar, used as the electrode, is submerged in the deionized water. After setting the proper parameters of the process, electrical energy is inputted to the electrode. The electrical energy is determined according to the applied electrical current and breakdown voltage. The waveform, pulse intensity and on-time period of the electrical current and voltage are shown in Fig. 2. Since the electrical energy produces the submerged arc with a high temperature ranging from 6000 to 12000° C, metal vaporization occurs in the vicinity of where the arc is generated and the Cu metal bar is vaporized rapidly ... nanoparticle size in length can increase up to more than 200 nm when no pressure control is implemented in the ASNSS. In other words, a higher pressure variation allows for a greater growth of the size of the nanoparticles. This is because the nucleating cell of metal aerosol has more time to grow before solidification when there is a higher pressure variation of the deionized water in the operating chamber."

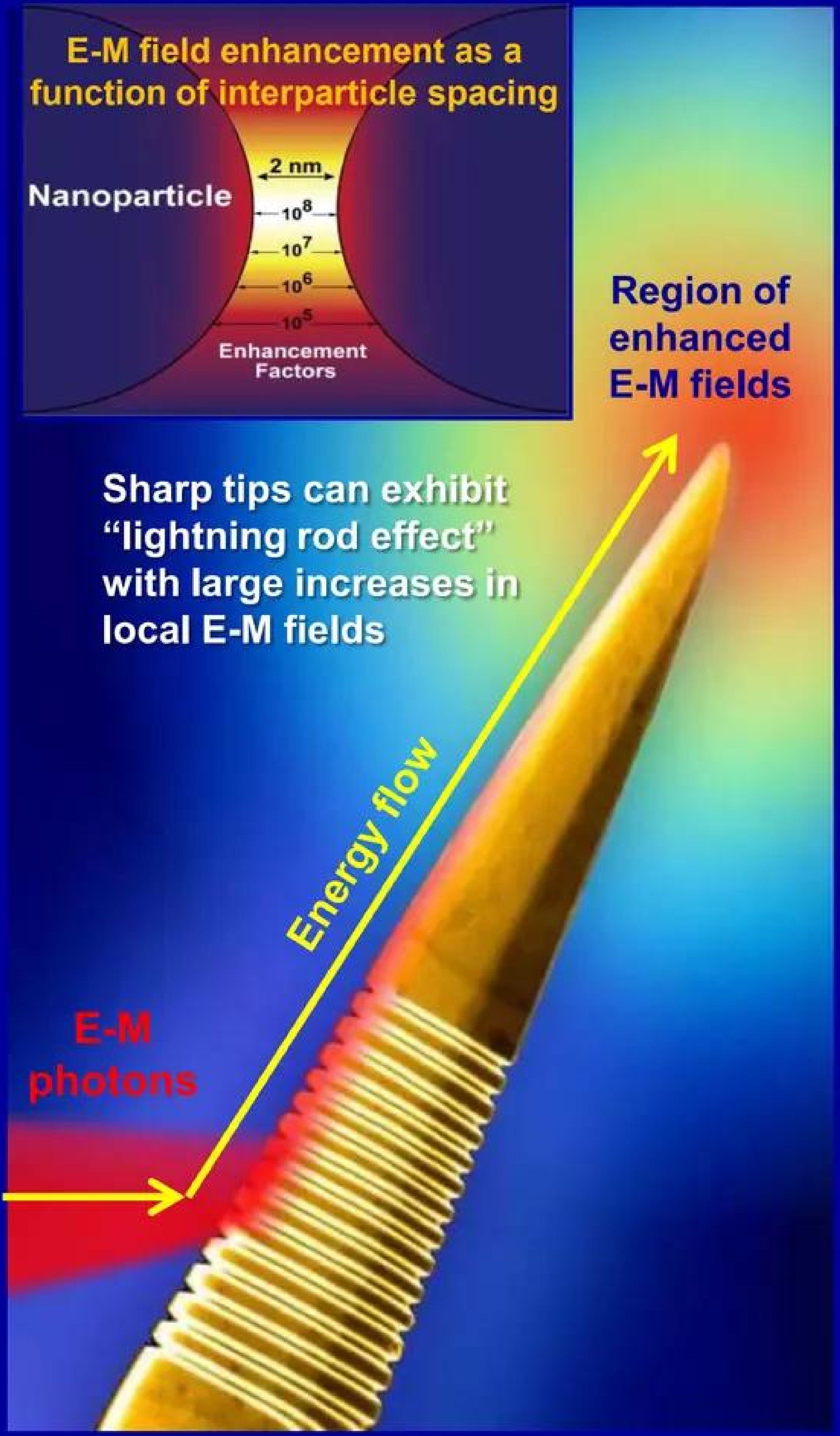
Carbon nanotubes found in blast furnace coke

" ... seems to be the result of a metal-catalyzed process involving a gas phase"

"*Carbon tubular morphologies in blast furnace coke*"
S. Gornostayev and J. Harkki
***Research Letters in Materials Science* v2008 Article ID 751630 (2008)**
http://downloads.hindawi.com/journals/amse/2008/751630.pdf

Abstract: "The paper reports on the first occurrence of microscale carbon tubular morphologies (CMTs) in a blast furnace (BF) coke. The CMTs were probably formed as a result of the conversion of solid disordered carbon via liquid phase metal particles involving a gas phase containing a substantial amount of N_2 and O_2. The presence of CMTs may lie behind the generation of the smallest fraction of fines in BF exhaust dust. If the amount of CMTs present in the BF exhausts gases at any particular metallurgical site proves to be substantial, it could become a subject of environmental concern."

Quoting conclusions from body of paper: "CMT-like carbon tubular morphologies can be formed in a BF coke. (ii) They are associated with graphite crystals and are formed later than their graphitic hosts. (iii) The appearance of CMTs and associated graphite seems to be the result of a metal-catalyzed process involving a gas phase containing a substantial amount of N_2 and O_2. (iv). the presence of CMTs may lie behind the generation of the smallest fraction of fines in BF exhaust dust. If the amount of CMTs present in the BF exhaust gases at any particular metallurgical site proves to be substantial, it could become a subject of environmental concern. Modern iron production facilities can control this form of pollution, for example, by installing monitoring stations to measure the amounts of inhalable particles (under 10 *μm*) in the air."



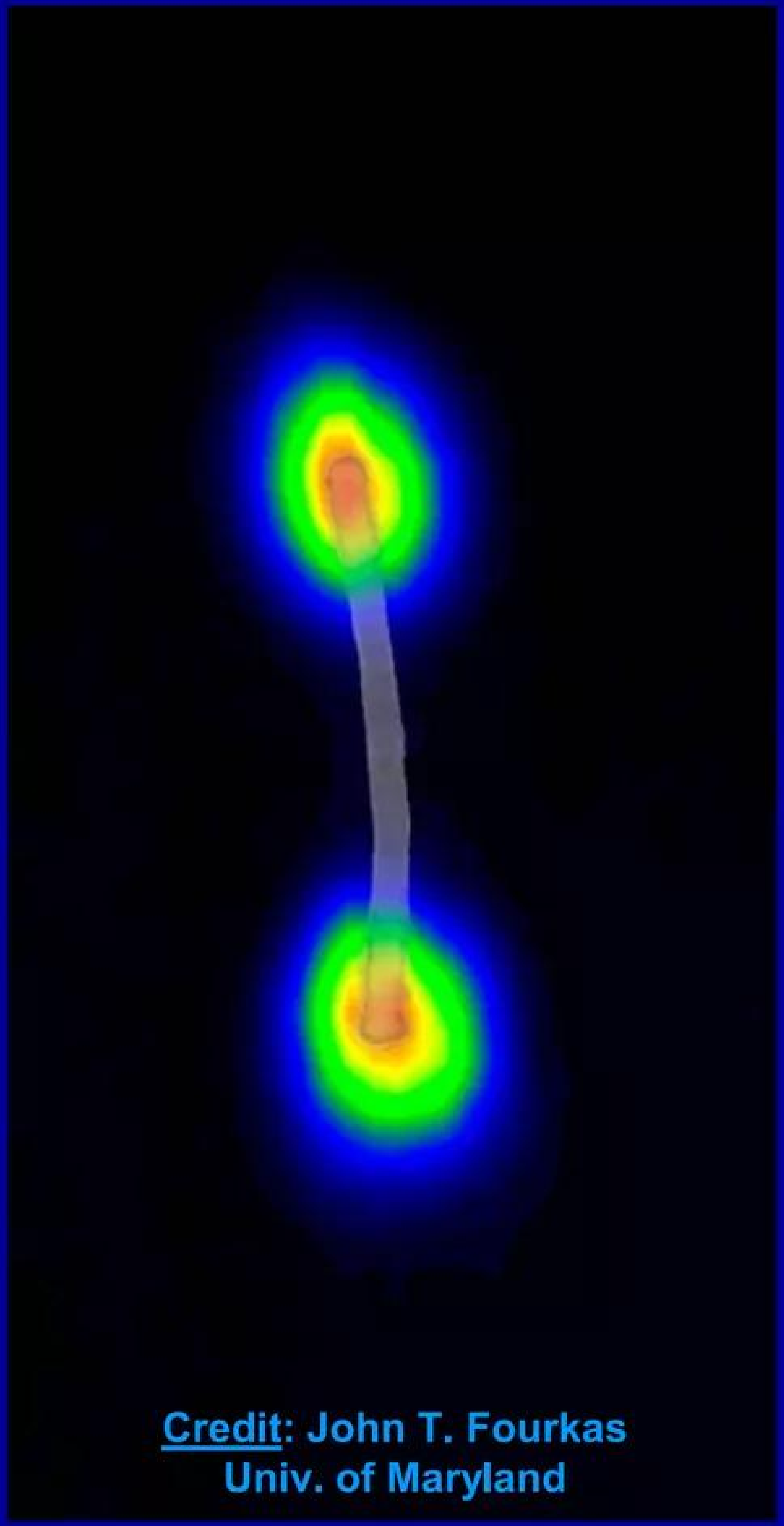
Carbon nanotubes found in diesel engine exhaust soot

"Raman spectroscopy and X-ray diffraction ... shows ... carbon nanotubes"

"*Morphological characterization of soot from the atmospheric combustion of diesel fuel*"
E. Dikio
Int. Journal of Electrochemical Science 6 pp. 2214 - 2222 (2011)
http://www.electrochemsci.org/papers/vol6/6062214.pdf

Abstract: "Diesel oil used as fuel in motor engines has been used as a precursor for the production of carbon nanomaterial without a catalyst precursor. Nanomaterials formed in the process were analysed by High resolution transmission electron microscope, (HR-TEM), Raman spectroscopy, scanning electron microscope (SEM), energy dispersive spectroscopy (EDS), thermogravimetric analysis (TGA) and X-ray diffraction (XRD). Carbon nanomaterial produced from diesel soot show the morphology of carbon nanospheres mixed with carbon nanotubes. The results obtained are presented. "

Quoting conclusions from body of paper: "Carbonaceous soot produced from diesel without a catalyst precursor show the presence of significant amount of carbon nanomaterial. The HR-TEM micrographs provide a clear indication that these nanoparticles are carbon nanospheres. Raman spectroscopy and X-ray diffraction investigation shows the presence of carbon nanotubes in association with amorphous nanomaterial due to the presence of the D and G bands found in carbon nanotubes. EDS analysis of diesel soot provide strong evidence of soot particles to be composed of primarily carbon and oxygen. The presence of a peak corresponding to sulphur is recorded in the EDS analysis."



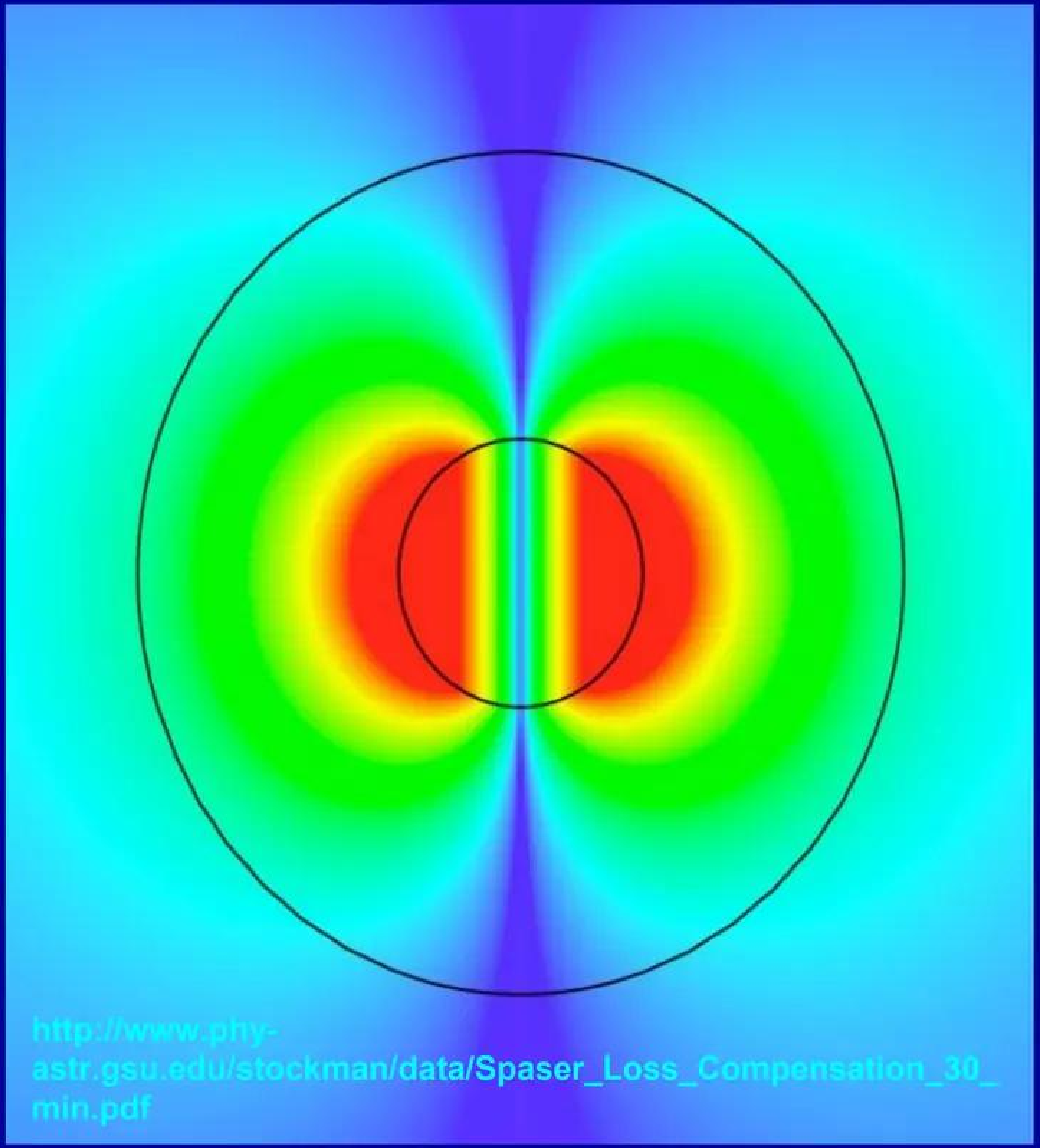
Credit: John T. Fourkas
Univ. of Maryland

Carbon nanotube arrays can transfer mega-ampere currents

Tantalizing future possibilities for engineering LENR-active nanostructures

"*Macroscopic transport of mega-ampere electron currents in aligned Carbon-nanotube arrays*"
G. Chatterjee *et al.*
***Physical Review Letters* 108 pp. 235005 - 235010 (2012)**
http://prl.aps.org/abstract/PRL/v108/i23/e235005

Abstract: "We demonstrate that aligned carbon-nanotube arrays are efficient transporters of laser-generated mega-ampere electron currents over distances as large as a millimeter. A direct polarimetric measurement of the temporal and the spatial evolution of the megagauss magnetic fields (as high as 120 MG) at the target rear at an intensity of (10^{18} - 10^{19}) W/cm^2 was corroborated by the rear-side hot electron spectra. Simulations show that such high magnetic flux densities can only be generated by a very well collimated fast electron bunch."



SPASER device's electric fields (2009): surface plasmon amplification by stimulated emission of radiation

http://www.phy-astr.gsu.edu/stockman/data/Spaser_Loss_Compensation_30_min.pdf

Image: http://opfocus.org/content/v7/s5/opfocus_v7_s5.pdf

Final thoughts and conclusions

Fullerenes and Graphene: exciting future potential as LENR-active substrates

- ✓ **While the conjectured theoretical mechanism for their data was erroneous, it appears that the carefully executed high-current Carbon-arc experiments at Texas A&M and BARC that were published in *Fusion Technology* in 1994 probably did in fact produce anomalous transmutation products**
- ✓ **Herein, we have shown how these previously inexplicable results can be understood with the assistance of the Widom-Larsen theory of LENRs and its extension to fullerenes and Graphene as viable LENR-active substrates**
- ✓ **We have also provided examples which suggest that the rich, rapidly advancing chemistry of fullerenes and Graphene/Graphane might be fruitfully applied to the design and fabrication of better devices having LENR-active surfaces; amazingly, chemical and nuclear processes can work side-by-side and likely interoperate in real-time on such surfaces**
- ✓ **In other Lattice SlideShare presentations, we have shown how mass spectroscopy results reported in peer-reviewed journals reveal isotopic anomalies in processes that also happen to produce CNTs and Graphene, e.g., hydrous pyrolysis, coke production, catalytic converters, and varied electric arc discharges, among others. That said, the burning question is what % of these isotopic and elemental anomalies are simply the result of chemical fractionation processes versus those caused by ‘exotic’ LENRs?**
- ✓ **Astronomers have recently reported detection of fullerenes and maybe Graphene in a hydrogen-rich dusty nebula of another galaxy. Given our discussions here, could non-stellar LENRs be occurring in such regions?**

2010 - 2011: Spitzer IR telescope detects first signatures of Fullerenes and Graphene in another galaxy

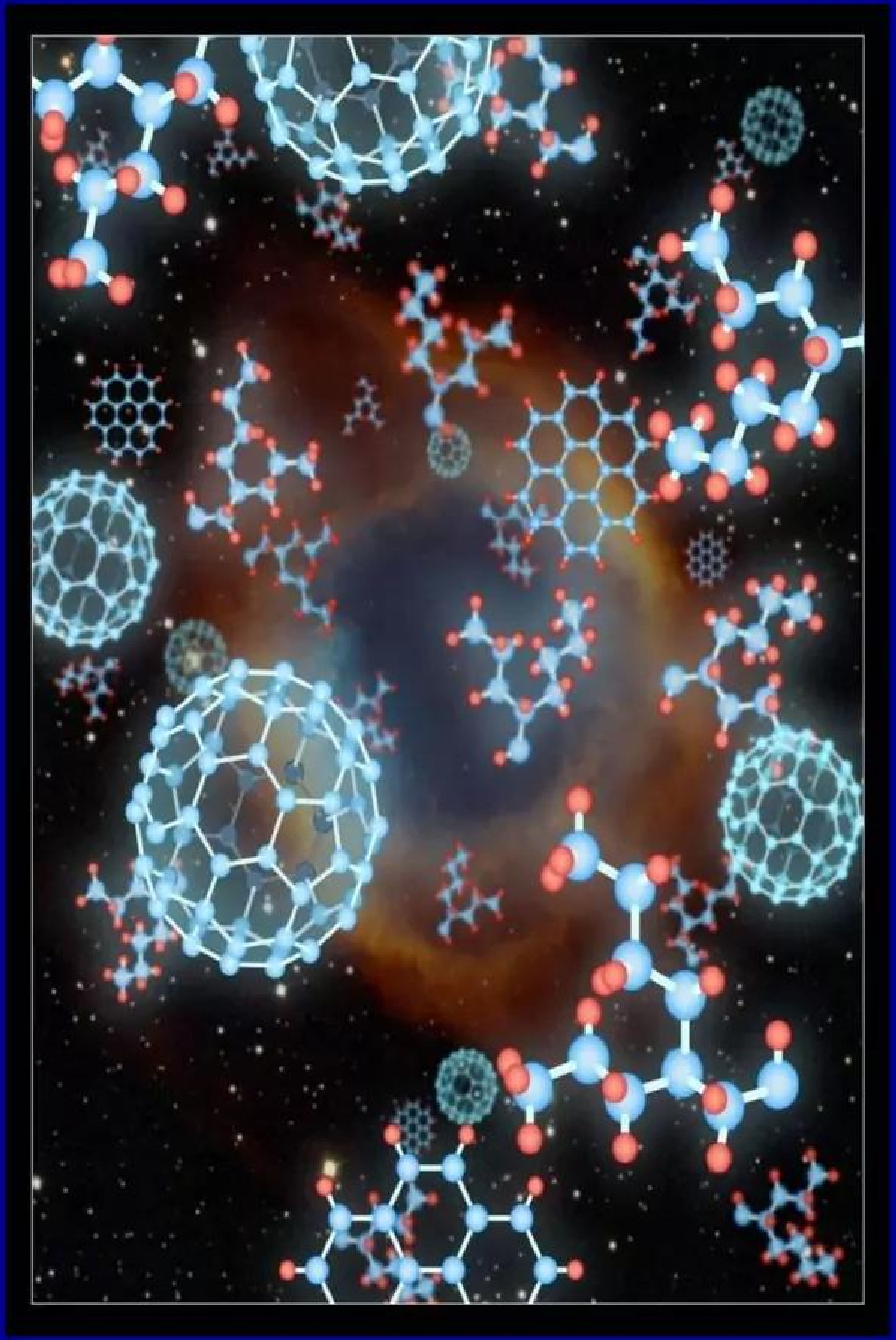


Image Credit: Pete Marenfeld (NOAO)

What follows for the remainder of this document is a selected subset of slides extracted from a previously released Lattice presentation as follows (note: section discussing our hypothesis of SPs on fullerenes and Graphene has been reordered toward front versus original version):

"Carbon-seed LENR Networks"
Lewis Larsen, Lattice Energy LLC, September 3, 2009
[65 slides - not peer-reviewed]
http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

This unusual step was undertaken to save readers from extra inconvenience and time associated with flipping back-and-forth between two Lattice PowerPoint presentations in order to follow the discussion

Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

Low Energy Nuclear Reactions (LENRs)

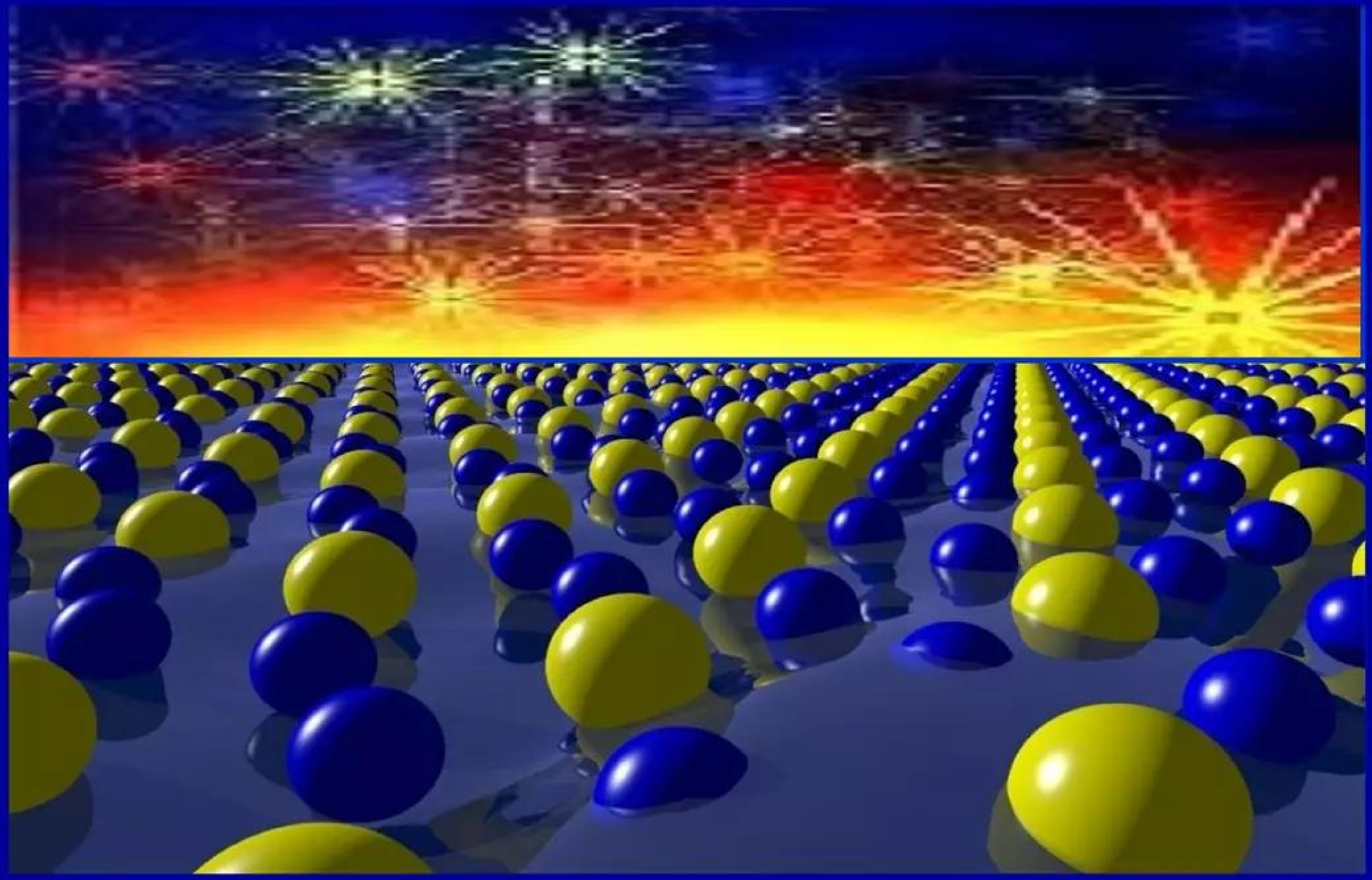
Ultra low momentum neutron (ULMN) capture on Carbon (C) seed nuclei: W-L theory, model LENR nucleosynthetic networks, and review of selected LENR experiments

Technical Overview

Lewis Larsen, President and CEO

> ***"Facts do not cease to exist because they are ignored."***
>
> ***Aldous Huxley in***
> ***"Proper Studies" 1927***

Are LENRs connected with hydrogenated fullerenes and graphene?



Where nuclear science meets chemistry?

Are LENRS connected with hydrogenated fullerenes? - I

How might W-L theory operate in the absence of hydride-forming metals?

- ✓ Let us recall how W-L theory 'works' on surfaces of hydride-forming metals, e.g., Pd, Ni, Ti. Specifically, triggering LENRs requires (for details please see our 2006 EPJC paper):
  - **Many-body 'films' consisting of collections of collectively oscillating electrons –** they consist of surface plasmon polariton electrons (SPPs) on metallic surfaces
  - **Many-body collections ('patches') of collectively oscillating light hydrogenous atoms –** comprise protons, deuterons, or tritons found within many-body 'patches' located on surfaces of highly hydrogen-loaded metallic hydrides, e.g., Pd, Ni, Ti
  - **Breakdown of Born-Oppenheimer approximation –** this enables mutual coupling and energy transfers between quantum mechanically 'entangled' patches of collectively oscillating hydrogenous atoms and nearby 'entangled' SPP electrons
  - **Energy inputs to produce fluxes of 'catalytic' ULM neutrons –** types of energy inputs that can couple effectively with many-body, collectively-coherently oscillating condensed matter hydrogen-electron systems include: ion fluxes, electric currents, laser photons, and magnetic fields, among others
- ✓ Answering the question reduces to whether carbon-arc systems contain or readily synthesize carbon-based structures that have: collective surface electron oscillations that are analogous to SPPs; surfaces that can support collectively oscillating patches of hydrogenous atoms; and breakdown of Born-Oppenheimer

Lattice Energy LLC

Are LENRS connected with hydrogenated fullerenes? - II

Can hydrogenated fullerene/graphene structures replace metals in LENRs?

- ✓ **Hypothesis**: π electrons that are found on surfaces of planar graphene or curvilinear fullerene carbon structures oscillate collectively, just like SPP electrons on metals; hydrogen atoms (protons) sticking 'above' surfaces of hydrogenated graphene and/or fullerenes also oscillate collectively, thus forming many-body 'patches' analogous to those that form on the surfaces of hydrogen-loaded metals; and, Born-Oppenheimer approximation breaks down on graphene and fullerene surfaces
- ✓ **Present evidence for the above hypothesis**: is as follows
  - If the above hypothesis were true, it would readily explain experimental results of ca. 1994 carbon-arc in H_2O experiments
  - Born-Oppenheimer is now known to break down on surfaces of fullerene structures (directly observed in 2009 paper at right)
  - Fullerenes/nanotubes are synthesized in carbon-arcs; S & B and Singh et al. were unaware of this fact (2003 paper cited at right)
  - Carbon isotope anomalies, excess heat, and low-level gamma emissions reported during phenanthrene hydrogenation (right)
- ✓ **Need for future experimentation**: clearly, a large number of new experiments would be required to fully investigate and validate this new conjecture regarding carbon-based LENR systems

Bushmaker et al., "Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes" in Nano Letters 9 (2) pp. 607-611 Feb. 11, 2009

In ref. [9] this fullerene thermochemical synthesis paper actually cites S&B's 1994 Fusion Technology article that has been discussed herein:

Lange et al., "Nanocarbon production by arc discharge in water," Carbon 41 pp. 1617-1623 2003

Hydrogenation of various carbon structures could potentially occur in the environment of carbon-arcs in H_2O. In that regard, synthesis of hydrogenated graphene (graphane) was first reported this year:

Elias et al., "Control of graphene's properties by reversible hydrogenation: evidence for graphane," Science 323 pp. 610-613 2009

In 2008, Tadahiko Mizuno, a well known Japanese LENR researcher, for the first time published direct experimental evidence that LENRs can occur on carbon structures. If his surprising results can be confirmed by other researchers, it would appear to imply that LENRs can potentially occur on other types of carbon structures such as phenanthrene - polycyclic aromatic hydrocarbon with three fused benzene rings

Mizuno, "Anomalous heat generation during the hydrogenation of phenanthrene," results presented at ICCF-14 conference, Washington, DC, in August 2008 See: http://www.lenr-canr.org/acrobat/MizunoTanomaloushb.pdf

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Are LENRS connected with hydrogenated fullerenes? - III

Hydrogenated fullerenes/graphene: where nuclear science meets chemistry?

- ✓ **Tip-off: Lange et al. (2003 - cited on previous slide) published some fascinating data, including what may be a large thermal anomaly in their carbon-arc experiments. Quoting:**

  "… the presence of atomic hydrogen … appears to be a new feature … Meanwhile, the discharge was accompanied by very strong and wide continuum radiation covering the visible and UV range."

  "The average plasma temperature in the water was quite high, ca. 4000 – 6500 K. The obtained temperatures for doped electrodes were within the same range. For the same of comparison, a reference test was carried out in He [gas] under atmospheric pressure and the same discharge conditions (40A and 21 V) [around 800W]. The obtained temperatures were ca. 1500 K lower than for discharge in water. Even at higher arc power input (>2 kW) in He the temperatures are still a few hundred degrees lower. It is apparent that the higher plasma temperature in water results from bubbles, which are small in number and volume, leading to high energy density."

  "Meanwhile, reactions among carbon, hydrogen, and hydrogen are highly exothermic. Under atmospheric pressure, the degree of dissociation of water into atomic oxygen and hydrogen is higher than 99% at ca. 5000K."

- ✓ **Interesting parallel and perhaps not just a coincidence: 4000 - 6500 K is about the same temperature range as LENR nuclear-active 'hot spots.' See Lattice Technical Overview dated June 25, 2009, Slides # 68, 70, 75, 76**

The following related papers are also interesting:

→ ***Subrahmanyam et al., "Simple method of preparing graphene flakes by an arc-discharge method," Journal pf Physical Chemistry 113 pp. 4257-4259 2009***

→ *Alternative methods for hydrogenation of graphene to synthesize graphane are discussed in:*

Luo et al., "Thickness-dependent reversible hydrogenation of graphene layers," ACSNano 3 pp. 1781-1788 2009

→ *News story about the first synthesis of graphane:*

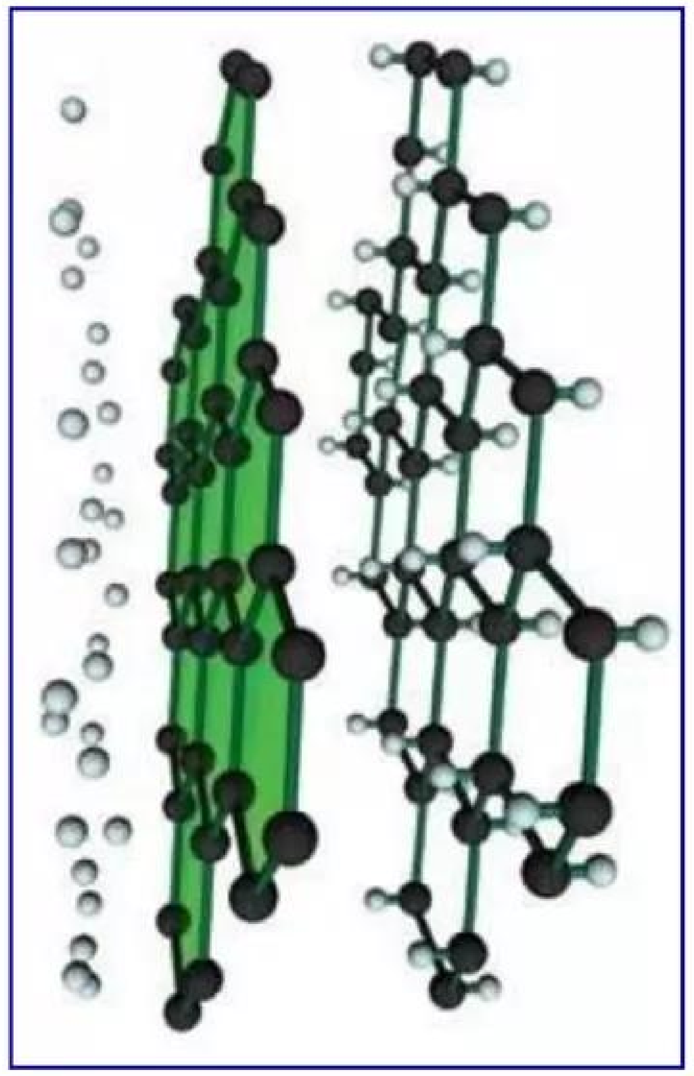
"Scientists discover ground-breaking material: Graphane," Physorg.com January 30, 2009

"The Manchester researchers produced high-quality crystals of graphane by exposing pristine graphene to atomic hydrogen."

From: http://www.physorg.com/news152545648.html

Here is an earlier theoretical reference in which they "…
→ *predict the stability of an extended two-dimensional hydrocarbon on the basis of first-principles total-energy calculations.":*

Sofo et al., "Graphane: A two-dimensional hydrocarbon," Physical Review B 75 pp. 153401 2007



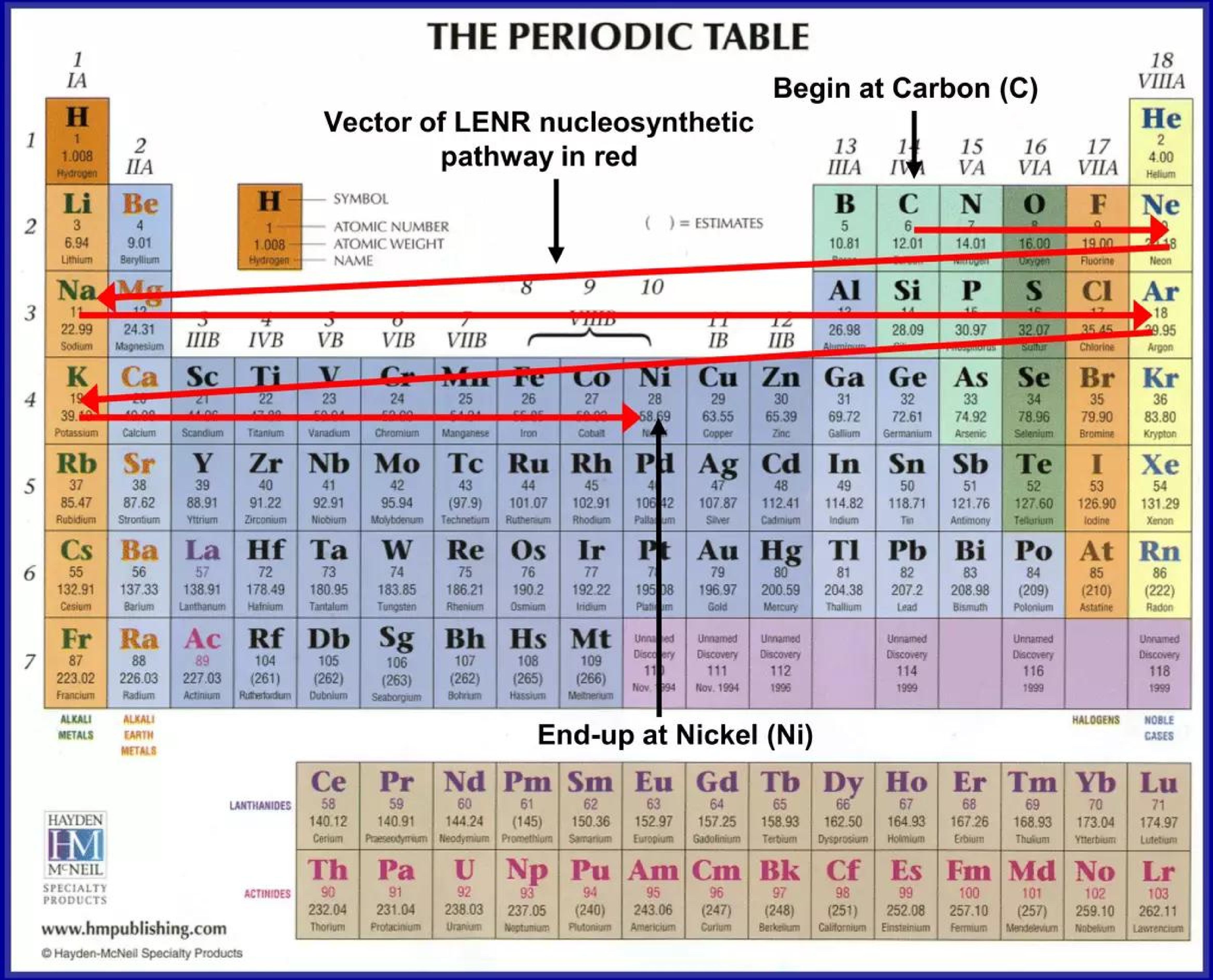
→ ***"Versatile graphene:** When a highly conductive graphene sheet is exposed to hydrogen atoms (white), they attach to the carbon atoms (black), transforming the material into graphane, an insulator. This is the first evidence that graphene's properties can be manipulated chemically. Credit: P. Huey/Science 323 2009"*

***From:** http://www.technologyreview.com/computing/22038/?a=f*

Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

Preview of Nucleosynthetic Pathways - I



Begin at Carbon (C)

Vector of LENR nucleosynthetic pathway in red

End-up at Nickel (Ni)

THE PERIODIC TABLE

H — SYMBOL
1 — ATOMIC NUMBER
1.008 — ATOMIC WEIGHT
Hydrogen — NAME

( ) = ESTIMATES

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H 1 1.008 Hydrogen																	He 2 4.00 Helium
2	Li 3 6.94 Lithium	Be 4 9.01 Beryllium											B 5 10.81 Boron	C 6 12.01 Carbon	N 7 14.01 Nitrogen	O 8 16.00 Oxygen	F 9 19.00 Fluorine	Ne 10 20.18 Neon
3	Na 11 22.99 Sodium	Mg 12 24.31 Magnesium											Al 13 26.98 Aluminum	Si 14 28.09 Silicon	P 15 30.97 Phosphorus	S 16 32.07 Sulfur	Cl 17 35.45 Chlorine	Ar 18 39.95 Argon
4	K 19 39.10 Potassium	Ca 20 40.08 Calcium	Sc 21 44.96 Scandium	Ti 22 47.88 Titanium	V 23 50.94 Vanadium	Cr 24 52.00 Chromium	Mn 25 54.94 Manganese	Fe 26 55.85 Iron	Co 27 58.93 Cobalt	Ni 28 58.69 Nickel	Cu 29 63.55 Copper	Zn 30 65.39 Zinc	Ga 31 69.72 Gallium	Ge 32 72.61 Germanium	As 33 74.92 Arsenic	Se 34 78.96 Selenium	Br 35 79.90 Bromine	Kr 36 83.80 Krypton
5	Rb 37 85.47 Rubidium	Sr 38 87.62 Strontium	Y 39 88.91 Yttrium	Zr 40 91.22 Zirconium	Nb 41 92.91 Niobium	Mo 42 95.94 Molybdenum	Tc 43 (97.9) Technetium	Ru 44 101.07 Ruthenium	Rh 45 102.91 Rhodium	Pd 46 106.42 Palladium	Ag 47 107.87 Silver	Cd 48 112.41 Cadmium	In 49 114.82 Indium	Sn 50 118.71 Tin	Sb 51 121.76 Antimony	Te 52 127.60 Tellurium	I 53 126.90 Iodine	Xe 54 131.29 Xenon
6	Cs 55 132.91 Cesium	Ba 56 137.33 Barium	La 57 138.91 Lanthanum	Hf 72 178.49 Hafnium	Ta 73 180.95 Tantalum	W 74 183.85 Tungsten	Re 75 186.21 Rhenium	Os 76 190.2 Osmium	Ir 77 192.22 Iridium	Pt 78 195.08 Platinum	Au 79 196.97 Gold	Hg 80 200.59 Mercury	Tl 81 204.38 Thallium	Pb 82 207.2 Lead	Bi 83 208.98 Bismuth	Po 84 (209) Polonium	At 85 (210) Astatine	Rn 86 (222) Radon
7	Fr 87 223.02 Francium	Ra 88 226.03 Radium	Ac 89 227.03 Actinium	Rf 104 (261) Rutherfordium	Db 105 (262) Dubnium	Sg 106 (263) Seaborgium	Bh 107 (262) Bohrium	Hs 108 (265) Hassium	Mt 109 (266) Meitnerium	Unnamed Discovery 110 Nov. 1994	Unnamed Discovery 111 Nov. 1994	Unnamed Discovery 112 1996		Unnamed Discovery 114 1999		Unnamed Discovery 116 1999		Unnamed Discovery 118 1999
	ALKALI METALS	ALKALI EARTH METALS															HALOGENS	NOBLE GASES

LANTHANIDES	Ce 58 140.12 Cerium	Pr 59 140.91 Praseodymium	Nd 60 144.24 Neodymium	Pm 61 (145) Promethium	Sm 62 150.36 Samarium	Eu 63 152.97 Europium	Gd 64 157.25 Gadolinium	Tb 65 158.93 Terbium	Dy 66 162.50 Dysprosium	Ho 67 164.93 Holmium	Er 68 167.26 Erbium	Tm 69 168.93 Thulium	Yb 70 173.04 Ytterbium	Lu 71 174.97 Lutetium
ACTINIDES	Th 90 232.04 Thorium	Pa 91 231.04 Protactinium	U 92 238.03 Uranium	Np 93 237.05 Neptunium	Pu 94 (240) Plutonium	Am 95 243.06 Americium	Cm 96 (247) Curium	Bk 97 (248) Berkelium	Cf 98 (251) Californium	Es 99 252.08 Einsteinium	Fm 100 257.10 Fermium	Md 101 (257) Mendelevium	No 102 259.10 Nobelium	Lr 103 262.11 Lawrencium

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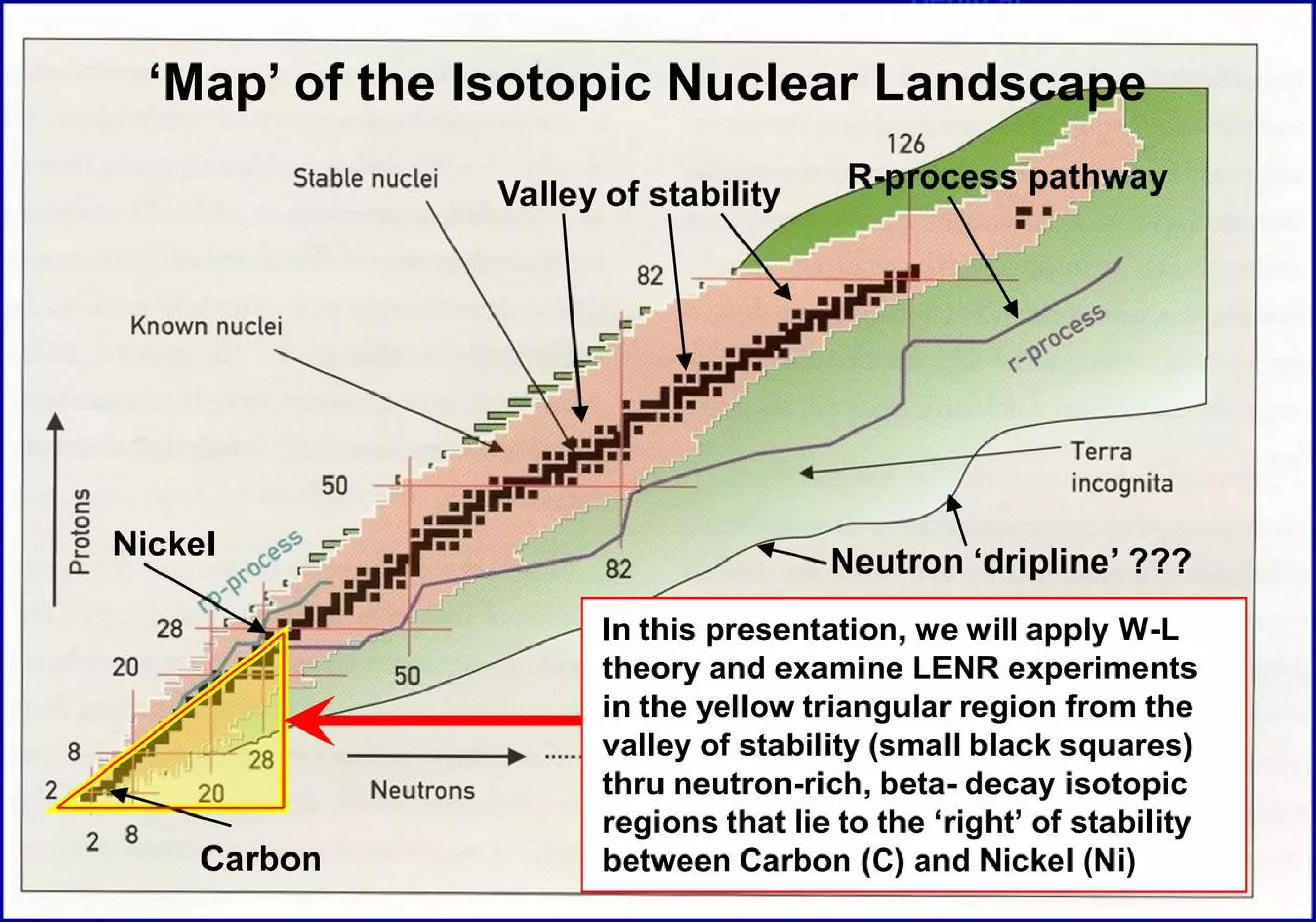
Preview of Nucleosynthetic Pathways - II

The neutron-catalyzed "r-process" (see path on chart) that astrophysicists believe occurs mainly in stellar supernova explosions is thought to produce most of the nuclei heavier than Iron (Fe). It operates in the neutron-rich region of the nuclear landscape to the right of the valley of stability to beta$^-$ decay. Extremely neutron-rich isotopes have a much wider variety of available decay channels in addition to 'simple' β$^-$.

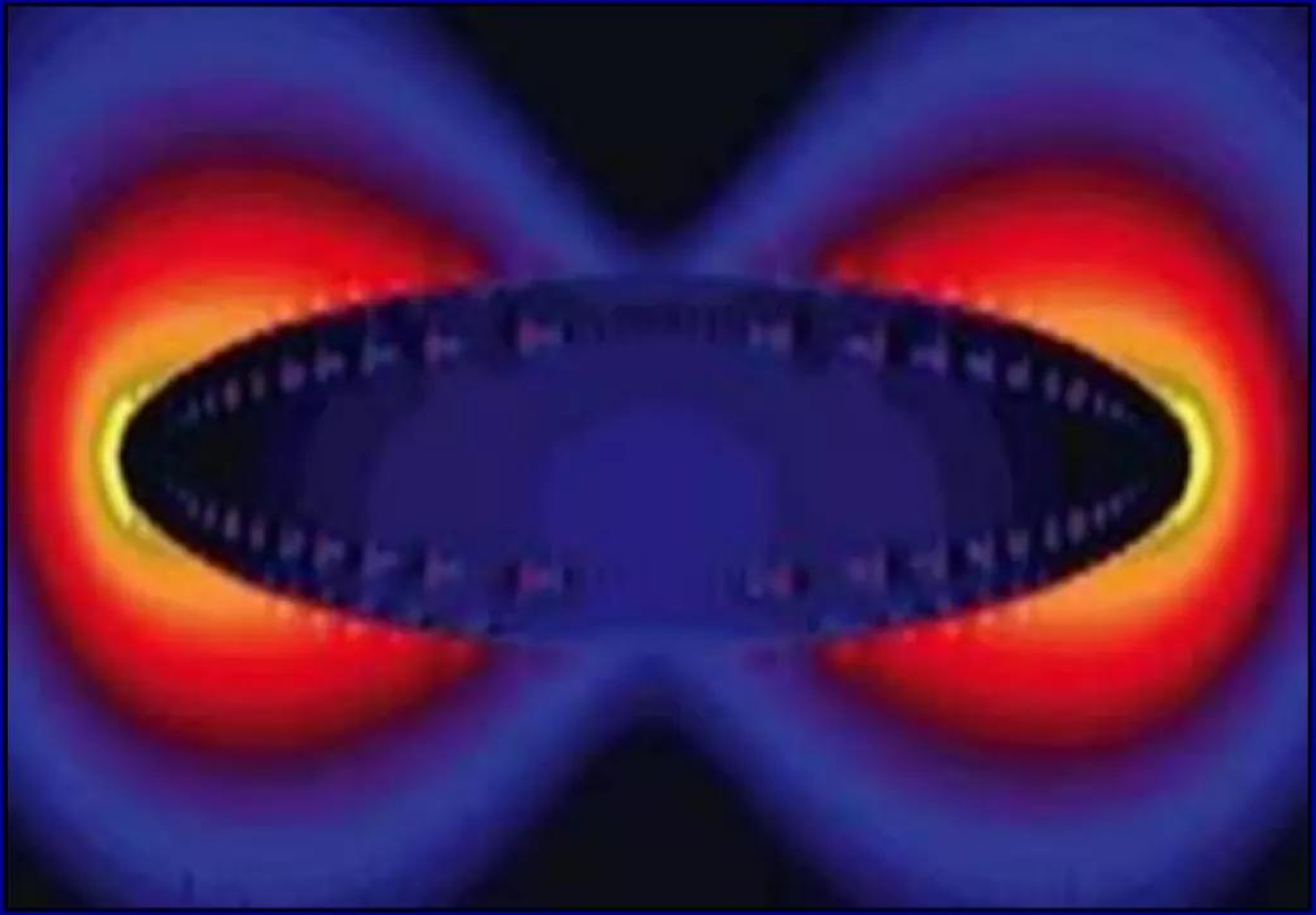
Begin at



In this presentation, we will apply W-L theory and examine LENR experiments in the yellow triangular region from the valley of stability (small black squares) thru neutron-rich, beta- decay isotopic regions that lie to the 'right' of stability between Carbon (C) and Nickel (Ni)

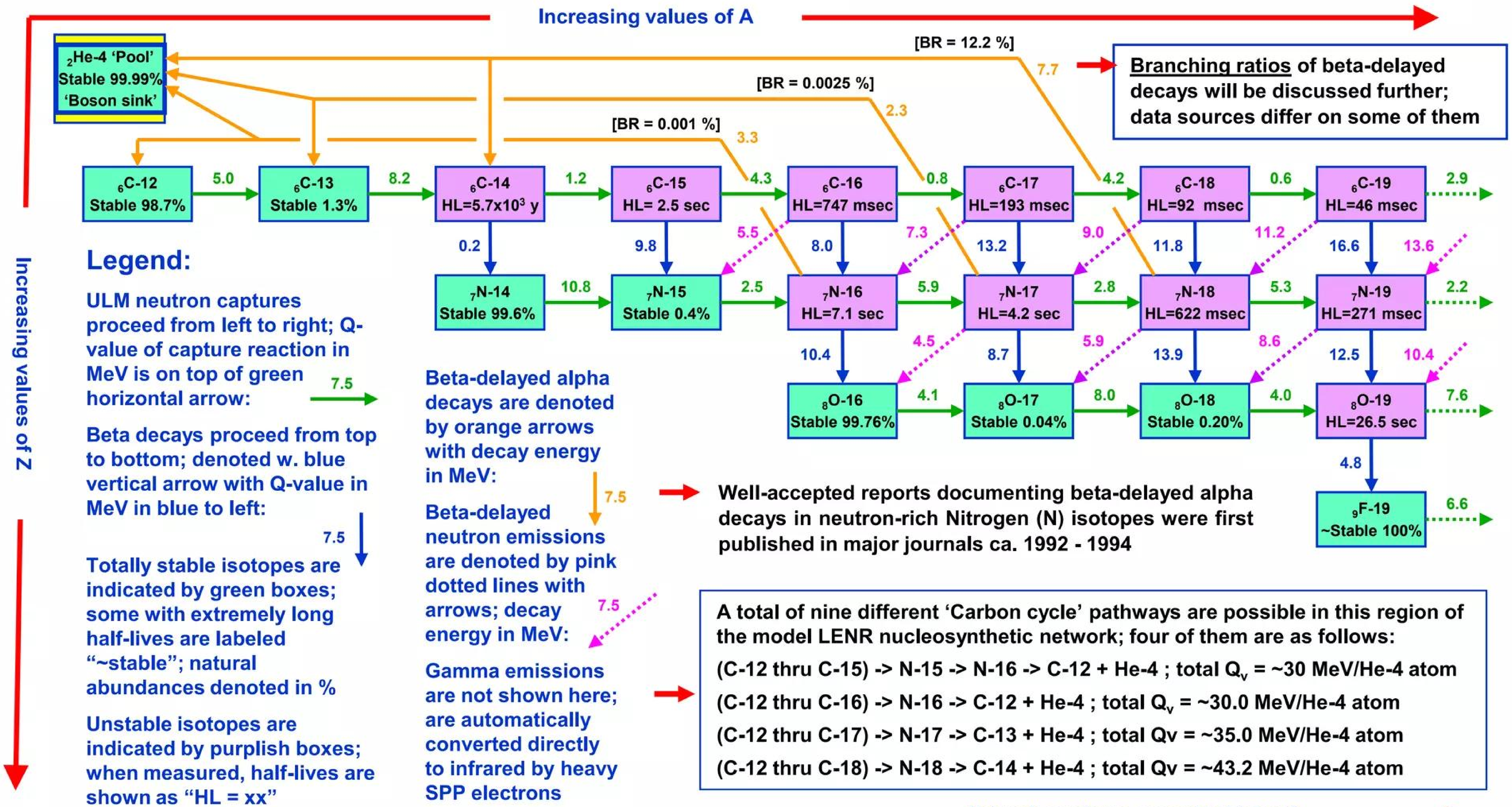
While they differ from stellar environments in many important aspects, LENR systems can produce large fluxes of a wide variety of extremely neutron-rich nuclei from low to very high values of A. Thus, they may someday be able to provide nuclear physics with a new and exciting, much lower-cost experimental tool for exploring the far reaches of the nuclear landscape and boundaries of nuclear stability. This possibility deserves further careful study.

W-L theory and carbon-seed nucleosynthetic networks



ULMN catalyzed LENR network starting from $_6C^{12}$ - I

ULMN capture on carbon, neutron-rich isotope production, and related decays



Branching ratios of beta-delayed decays will be discussed further; data sources differ on some of them

Legend:

ULM neutron captures proceed from left to right; Q-value of capture reaction in MeV is on top of green horizontal arrow:

Beta decays proceed from top to bottom; denoted w. blue vertical arrow with Q-value in MeV in blue to left:

Totally stable isotopes are indicated by green boxes; some with extremely long half-lives are labeled "~stable"; natural abundances denoted in %

Unstable isotopes are indicated by purplish boxes; when measured, half-lives are shown as "HL = xx"

Beta-delayed alpha decays are denoted by orange arrows with decay energy in MeV:

Beta-delayed neutron emissions are denoted by pink dotted lines with arrows; decay energy in MeV:

Gamma emissions are not shown here; are automatically converted directly to infrared by heavy SPP electrons

Well-accepted reports documenting beta-delayed alpha decays in neutron-rich Nitrogen (N) isotopes were first published in major journals ca. 1992 - 1994

A total of nine different 'Carbon cycle' pathways are possible in this region of the model LENR nucleosynthetic network; four of them are as follows:

(C-12 thru C-15) -> N-15 -> N-16 -> C-12 + He-4 ; total Q_v = ~30 MeV/He-4 atom

(C-12 thru C-16) -> N-16 -> C-12 + He-4 ; total Q_v = ~30.0 MeV/He-4 atom

(C-12 thru C-17) -> N-17 -> C-13 + He-4 ; total Qv = ~35.0 MeV/He-4 atom

(C-12 thru C-18) -> N-18 -> C-14 + He-4 ; total Qv = ~43.2 MeV/He-4 atom

Network continues onward to higher A

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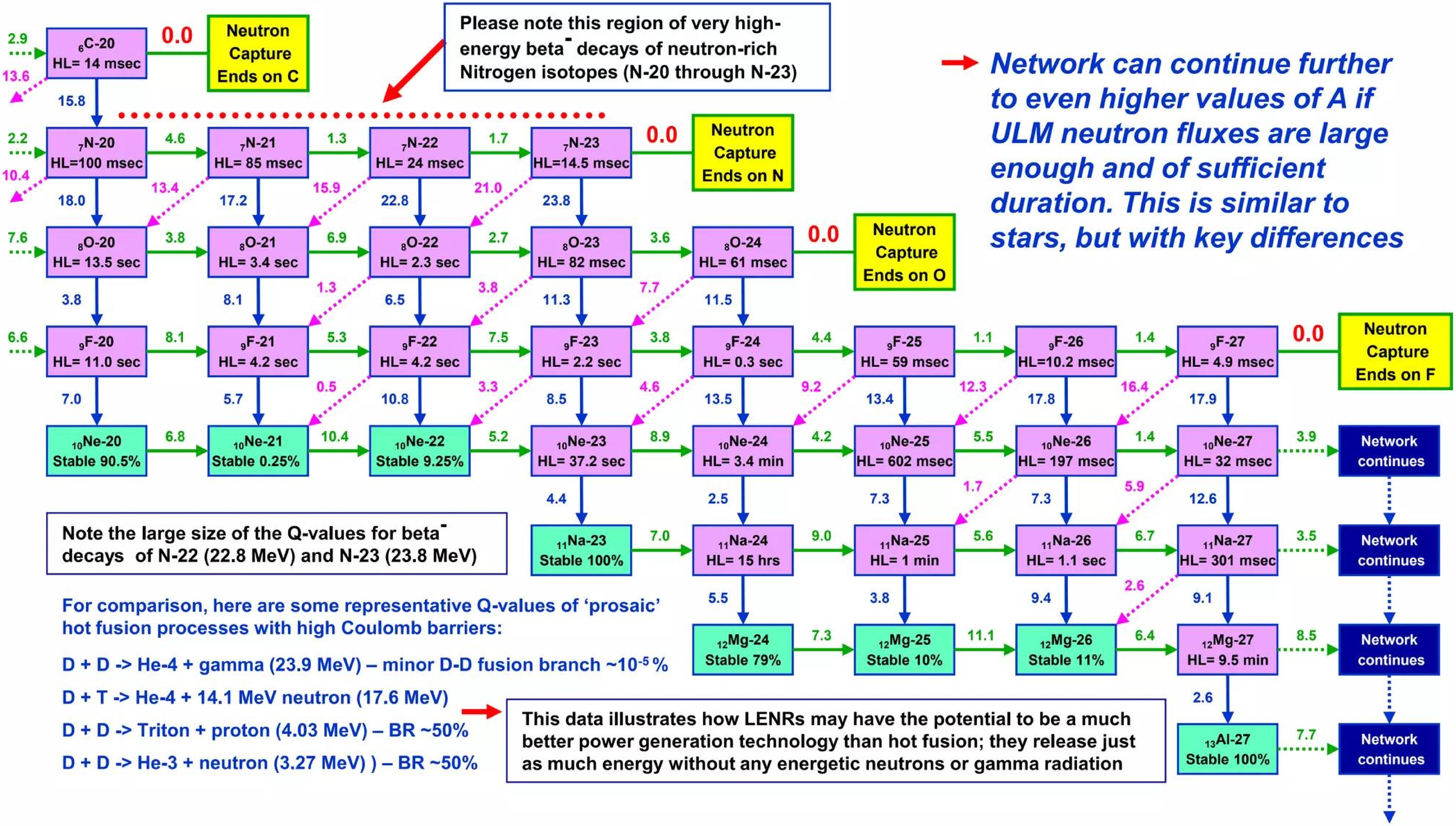
ULMN catalyzed LENR network starting from $_{6}C^{12}$ - II



Please note this region of very high-energy beta^{-} decays of neutron-rich Nitrogen isotopes (N-20 through N-23)

Network can continue further to even higher values of A if ULM neutron fluxes are large enough and of sufficient duration. This is similar to stars, but with key differences

Note the large size of the Q-values for beta^{-} decays of N-22 (22.8 MeV) and N-23 (23.8 MeV)

For comparison, here are some representative Q-values of 'prosaic' hot fusion processes with high Coulomb barriers:

D + D -> He-4 + gamma (23.9 MeV) – minor D-D fusion branch ~10^{-5} %

D + T -> He-4 + 14.1 MeV neutron (17.6 MeV)

D + D -> Triton + proton (4.03 MeV) – BR ~50%

D + D -> He-3 + neutron (3.27 MeV)) – BR ~50%

This data illustrates how LENRs may have the potential to be a much better power generation technology than hot fusion; they release just as much energy without any energetic neutrons or gamma radiation

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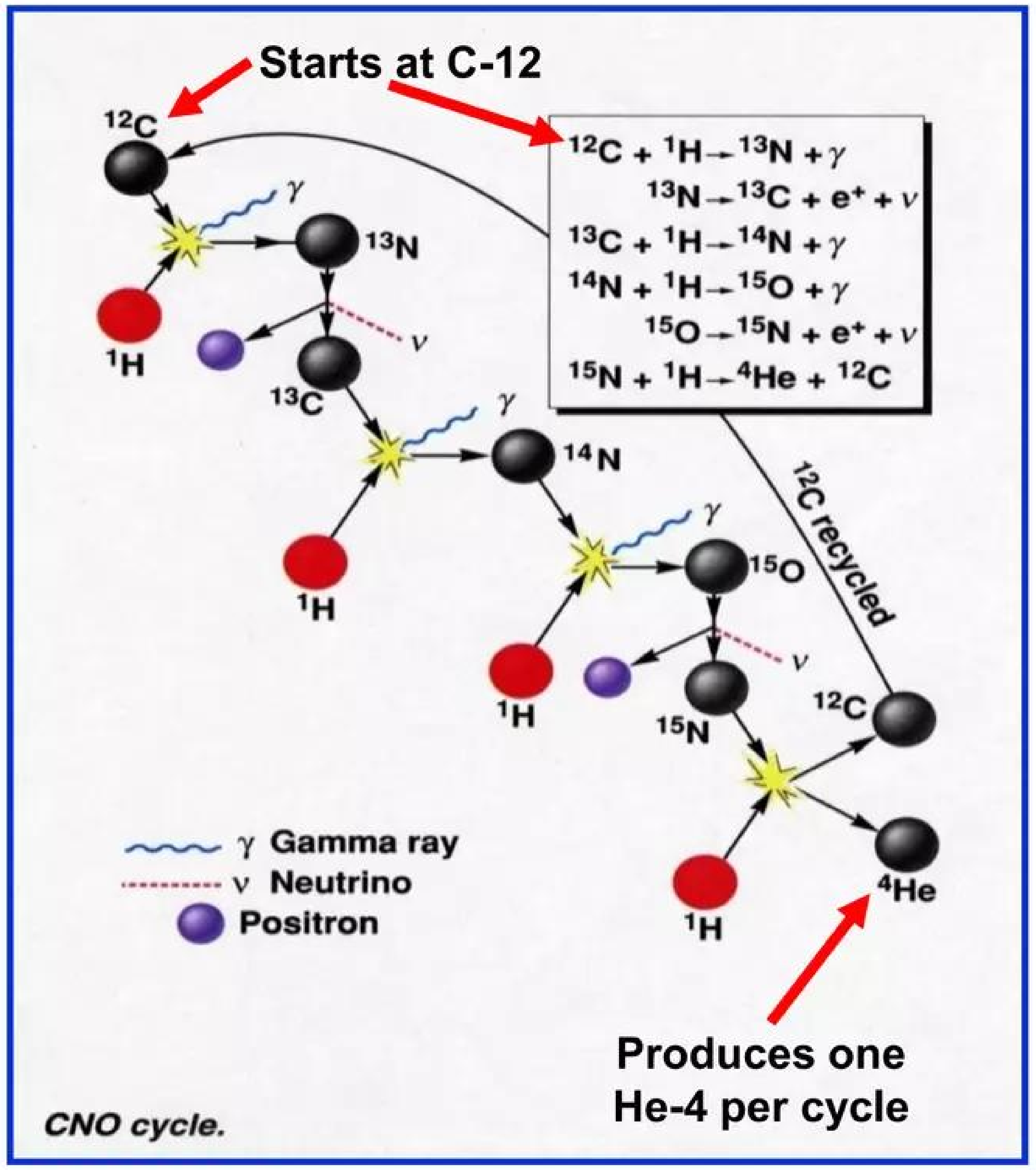
ULMN catalyzed LENR network starting from $_6C^{12}$ - III

Here is how <u>fusion-based</u> carbon cycles are thought to operate in stars

Cycle 1: stellar CNO nucleosynthetic cycle

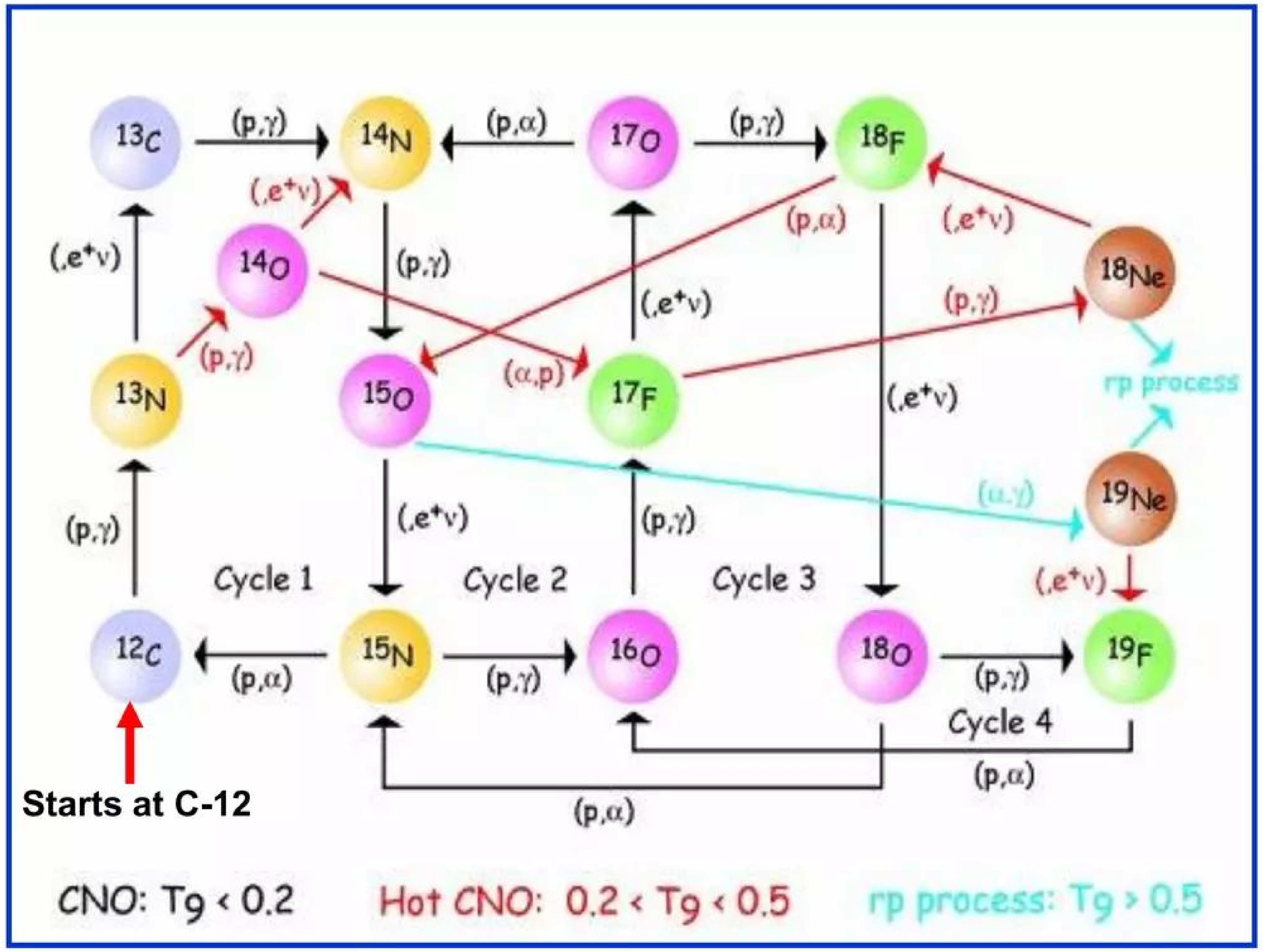


$^{12}C + {}^{1}H \rightarrow {}^{13}N + \gamma$
$^{13}N \rightarrow {}^{13}C + e^{+} + \nu$
$^{13}C + {}^{1}H \rightarrow {}^{14}N + \gamma$
$^{14}N + {}^{1}H \rightarrow {}^{15}O + \gamma$
$^{15}O \rightarrow {}^{15}N + e^{+} + \nu$
$^{15}N + {}^{1}H \rightarrow {}^{4}He + {}^{12}C$

Starts at C-12

Produces one He-4 per cycle

Cycles 1 – 4: CNO + 3 nucleosynthetic cycles thru Ne-18 and Ne-19



Starts at C-12

<u>Comments</u>: in the stellar CNO cycle only C-12 is recycled; in LENR-based carbon cycles, C-12, C-13, and C-14 are all potentially regenerated. In general, ULMN catalyzed nucleosynthetic networks involve production of substantially more neutron-rich isotopes than stellar networks, e.g., C-14⇨C-20; N-14⇨N-23; O-19⇨O-24; F-19⇨F-27; and Ne-20 ⇨Ne-27. Alpha decays are far more common events in low-A stellar fusion processes

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ULMN catalyzed LENR network starting from ${}_{6}C^{12}$ - IV

Discussion of ULM neutron captures starting with Carbon 'seeds'

- ✓ **Large Q-values for beta decays of neutron-rich isotopes (up to 23.8 MeV in this region of the nucleosynthetic network) created in LENR systems produce unstable 'daughter' nuclei in highly excited states; this environment is favorable to beta-delayed decay processes wherein nuclei have wider range of dynamic 'choices' for alternative decay channels**

- ✓ **As shown in Carbon-seed nucleosynthetic network diagrams, ULM neutron capture on Carbon isotopes can produce Helium-4 via beta-delayed alpha decay channels, which under normal circumstances would be unusual for typical nuclei at such values of A**

- ✓ **As measured in neutron-rich fragments collected and analyzed in RNB particle collider experiments, branching ratios for beta-delayed alpha decays of Nitrogen isotopes are presently thought to be: N-16 (0.001 %); N-17 (0.0025 %); and N-18 (12.2 %)**

- ✓ **There is reason to believe that such alpha branching ratios could be substantially different for operating LENR systems in which dense local populations of heavy (energetic) SPP electrons and very neutron-rich nuclei simultaneously coexist with large fluxes of ULM neutrons. In such environments, high occupation of local fermionic states may hinder beta-delayed emission of <u>fermions</u> (neutrons and electrons – i.e., beta particles) into the local continuum. All other things being equal, it may be 'easier' for nuclei to emit <u>bosons</u> (He-4 particles and gamma photons) that can quickly 'bleed-off' excess energy to de-excite**

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ULMN catalyzed LENR network starting from $_6C^{12}$ - V

Discussion of ULM neutron captures starting with Carbon ‘seeds’

- ✓ **Depending on the Q-value of the related beta decay, beta-delayed neutrons have particle energies that can range from as little as ~18 keV up to ~5$^+$ MeV (e.g., N-22); however, maximum measured neutron energies published in the literature are typically from <1 - 2 MeV with peaks in their statistical distributions often falling between 0.25 - 0.50 MeV**

- ✓ **While beta-delayed neutron decays and their related Q-values are shown in the network diagrams, they do not appear to have substantial production cross-sections in LENR systems. This conclusion is based on fact that in 20 years of episodically intense measurement efforts, large fluxes of energetic neutrons have never been observed in any LENR system. What is occasionally seen in experiments where neutrons are measured are relatively small, ‘bursty’ fluxes of relatively low-energy neutrons that do not appear to correlate strongly with the presence or absence of heat production. Indeed, one of the early criticisms of “cold fusion” was that MeV-energy neutron production was many orders of magnitude less than what would normally be expected from prosaic D-D fusion reactions**

- ✓ **In some LENR systems, small amounts of beta-delayed neutron emissions may occur as a given micron-scale, nuclear-active ‘patch’ site is in the process of ‘shutting down.’ That is, when production of heavy electrons and ULM neutrons declines in such a site, unoccupied fermionic states can then begin to open-up in the local continuum, allowing previously ‘frustrated’ beta decays to proceed that can in turn produce delayed neutron emissions**

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ULMN catalyzed LENR network starting from $_6C^{12}$ - VI

Nine different 'carbon cycle' pathways can occur within the network

- ✓ **Model nucleosynthetic network herein has a total of nine possible pathways that function as 'leaky' carbon cycles, regenerating C-12, or C-13, or C-14 and producing one He-4 atom (alpha particle) per cycle**
- ✓ **Total 'raw' Q-values for the model's 9 different carbon cycles range from ~30.0 MeV/He-4 to ~43.2 MeV/He-4; when you adjust for the energetic 'cost' of making ULM neutrons, net Q_vs range from ~28.4 to ~40.9 MeV/He-4**
- ✓ **These LENR carbon cycles are 'leaky' in that they are an incidental byproduct of a ULM neutron-driven nucleosynthetic network that is constantly 'trying' to produce stable nuclei at higher and higher values of A**
- ✓ **He-4 is a boson; has no 'Fermi pressure' issues with occupied local states like neutrons and electrons. Can serve as a 'bosonic sink' in LENR systems; also can readily leave nuclear-active sites in the form of a gas**
- ✓ **LENR carbon cycles will continue to operate as long as ULM neutrons are available to 'drive' reaction network**

→ *Please see the Wikipedia article about the CNO 'carbon cycle' in stars at:* ***http://en.wikipedia.org/wiki/CNO_cycle***

In stars hotter and more massive than our sun, CNO-I cycle produces 26.77 MeV/He-4

→ *Adjusted net Q_vs (assume D used to make ULM neutrons; 'gross' Q_v is adjusted to reflect an input energy 'cost' of 0.39 MeV/neutron) for the model's nine different carbon cycle pathways are calculated as follows (in MeV): 40.86, 40.86, 33.05, 40.76, 32.95, 28.44, 40.76, 32.95, and 28.44/He-4*

Note: some pathways have identical net Q_v

→ *Based on branching values measured in isolated RNB fragments (12.2% for N-18) the four ~40 MeV paths might appear to be most probable. However, as we discussed, it appears very likely that these branching ratios could have very different values in operating LENR systems; for discussion purposes, let's assume that is true. Note that model's Q_vs fall into two groups: four high-energy paths (avg. net Q_v = 40.81) and five lower-energy paths (avg. net Qv = 31.17 MeV/He-4). A simple average of the two group average Q_vs is 35.99 MeV/He-4. Also note: all values larger than CNO-I in stars*

ULMN catalyzed LENR network starting from $_6C^{12}$ - VII

ULM neutron fluxes and traversing the Fluorine 'valley of death'

- ✓ **LENR nucleosynthetic networks operating in condensed matter have issues with produced Fluorine that are not present with ions in fusion-based stellar environments**
- ✓ **LENR-active micron-scale 'patch' sites in condensed matter systems must maintain coherent oscillations of protons or deuterons on surfaces for weak interaction ULMN production to continue locally without interruption**
- ✓ **Free Fluorine atoms or F_2 molecules produced by LENR network in nuclear-active 'patches' will react violently with any nearby hydrogen atoms (producing HF, DF, or TF), carbon atoms (making fluorinated carbons with ultra-strong C-F bonds), or metal atoms, e.g., ⇨PdF_6. Such energetic chemical reactions can disrupt coherence in 'patches,' thus creating a potential 'valley of death' that LENR networks must necessarily traverse in order to be able to create heavier elements at higher values of A**
- ✓ **Best strategy to traverse 'valley of death' is to combine very high rates of ULM neutron production with largest-possible physical dimensions of LENR-active 'patches'**

→ *Please see the redirected Wikipedia article on the chemistry of Fluorine at:* http://en.wikipedia.org/wiki/Flourine

→ *Also see a short article by:* ***T. Furuya and T. Ritter, "Carbon-Fluorine Reductive Elimination from a High-Valent Palladium Fluoride," J. Am. Chem. Soc. 130, pp. 10060 - 10061, 2008*** *at:*

http://www.chem.harvard.edu/groups/ritter/publications/page12/files/2008-10060j.pdf

In carbon-capture LENR systems, all other things being equal, the greater the input energy (e.g., in the form of electrical current) per unit of time, the higher the potential rate of ULM neutron production. The higher the neutron flux, the more effectively and quickly an LENR system will be able to traverse Fluorine's 'valley of death.' Systems producing much smaller neutron fluxes in comparison to well-performing aqueous electrolytic cells (e.g., using pressure and heat-driven H/D ion permeation-diffusion a la Iwamura et al.'s experiments) will likely have difficulty going beyond Oxygen, let alone Fluorine. Rates of chemical reactions can vary from 10^{-10} sec to > 1 second. In particular, for reactions $F + H_2 \Rightarrow HF + H$ and $F + D_2 \Rightarrow DF + D$ the measured rate constants at 195-294° K are 1.54×10^{-10} and 0.82×10^{-10} cm^3/sec. Therefore, the higher a ULM neutron production rate is ***above*** *the key value of 10^{10} cm^2/sec, the easier it will be for a Carbon-seed LENR network to produce higher-A isotopes beyond Fluorine*

→ *See:* ***Igoshin et al., "Determination of the rate constant of the chemical reaction $F + H_2(D_2) \Rightarrow HF(DF) + H(D)$ from the stimulated emission of HF molecules," Soviet Journal of Quantum Electronics 3 pp. 306-311 1974***

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ULMN catalyzed LENR network starting from $_6C^{12}$ - VIII

β decays of neutron-rich isotopes can release large amounts of energy

- ✓ **The good news about Uranium and Plutonium fission reactions is that they have Q_vs of ~190^+ MeV, releasing most of their energy on a time scale of ~10^{-19} seconds in the form of prompt neutron and gamma radiation as well as fast moving, neutron-rich, asymmetric fission fragments comprising unstable products that undergo further decays; bad news is production of large quantities of prompt 'hard' radiation and hazardous long-lived radioactive isotopes; massive shielding is mandatory**
- ✓ **Good news about 'cleaner' D-T fusion reactions in commercial power reactors is Q_v of ~17.6 MeV; bad news is that much of the energy released is in the form of hard to manage 14.1 MeV neutrons along with gammas and neutron-induced radioactivity in apparatus; high temps create huge engineering problems**
- ✓ **Good news about LENR-based nucleosynthetic networks is that they do not produce biologically significant quantities of hard gamma/neutron radiation or hazardous long-lived radioactive isotopes; in contrast to fission/fusion, no bad news for LENRs**
- ✓ **Many scientists mistakenly believe that weak interactions are weak energetically; that is incorrect. In network herein, N-17 and N-18 beta$^-$ decays release 22.8 and 23.8 MeV, respectively**

Please see:

France et al., "Absolute branching ratio of beta-delayed gamma-ray emission of ^{18}N"

http://arxiv.org/PS_cache/astro-ph/pdf/0307/0307129v2.pdf (2003)

Controversy about measurements:

***Buchmann et al., "Some remarks about β-delayed α-decay of ^{16}N"** at:*

http://arxiv.org/PS_cache/arxiv/pdf/0907/0907.5340v1.pdf (2009)

Other measurements:

C. S. Sumithrarachchi, PhD thesis, Michigan State University, "The study of beta-delayed neutron decay near the neutron drip line" at:

http://www.nscl.msu.edu/ourlab/publications/download/Sumithrarachchi2007_231.pdf (2007)

***Raabe et al., "Beta-delayed deuteron emission from ^{11}Li: decay of the halo" "** at:*

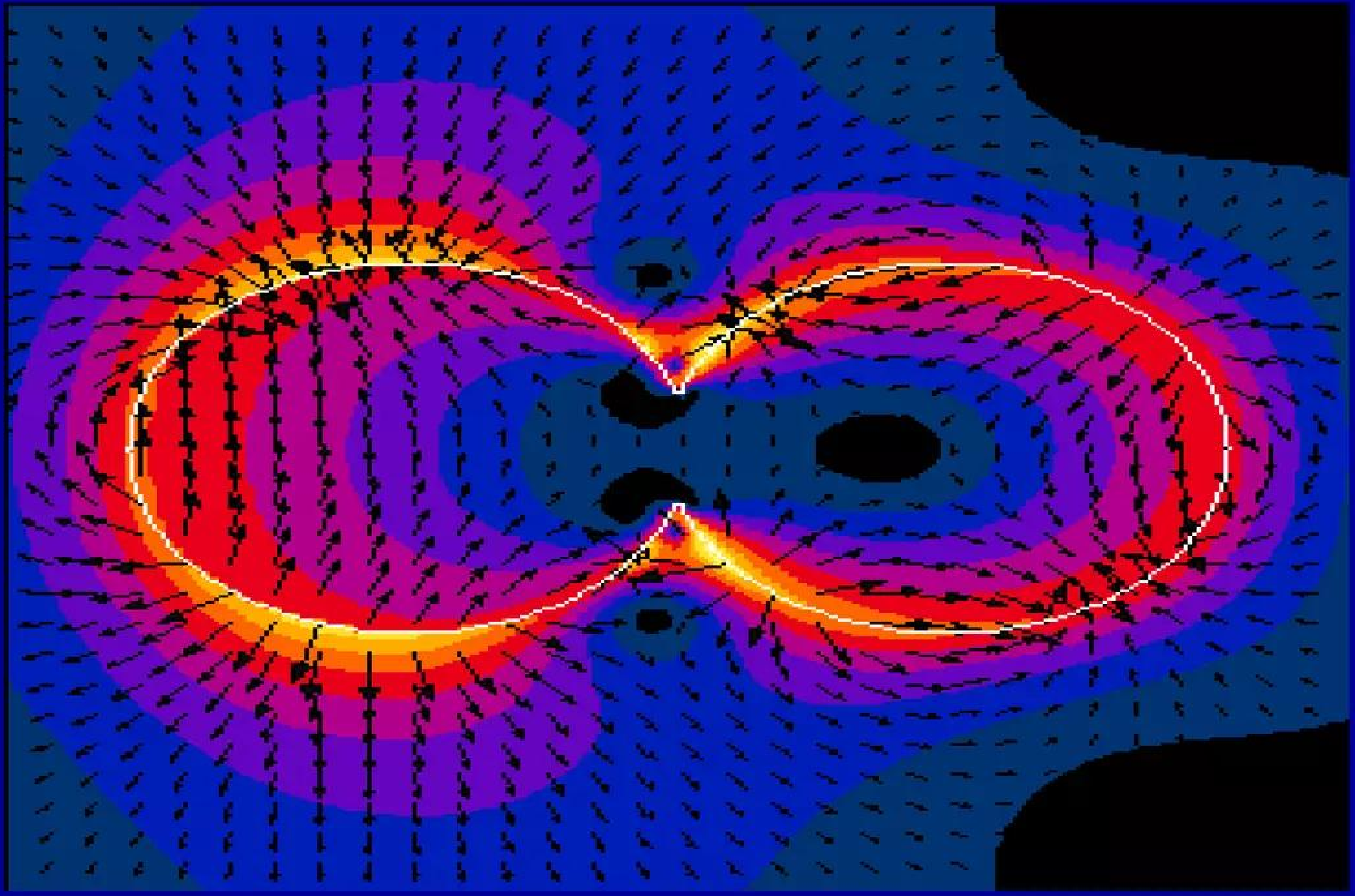
http://arxiv.org/PS_cache/arxiv/pdf/0810/0810.0779v1.pdf (2008)

Comment: please recall that fission and fusion reactions mainly involve the strong interaction, whereas key nuclear processes in LENRs involve weak interaction, i.e., ULM neutron production via e+p or e+d and beta decays

Review and discussion of LENR experiments - II

Primarily non-metallic Carbon substrates hosting nuclear-active sites

1994: Texas A&M carbon-arc/H_2O; Bockris and Sundaresan



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1994: Texas A&M experiments with carbon-arcs in H_2O - I

Sundaresan & Bockris decide to repeat Oshawa’s 1965 experiments

- ✓ **Employing somewhat strange scientific logic, in mid-1960s a little-known Japanese scientist by the name of George Oshawa conducted a series of experiments with electric arcs between pure carbon rods immersed in ordinary water in which he claimed to have transmuted Carbon (C) into Iron (Fe). Unable to explain the seemingly bizarre experimental results, he could not get his paper accepted by any refereed journal and was forced to publish it indirectly in a rather obscure venue**
- ✓ **Oshawa’s work was essentially forgotten until ca. 1992-1993, when John Bockris, a well-known electrochemist and Professor of Chemistry at Texas A&M University, and R. Sundaresan, then a visiting scientist at Texas A&M from the Bhabha Atomic Research Center (BARC) in India, became aware of it. They decided to collaborate and repeat the carbon-arc transmutation experiments**
- ✓ **Reference to Oshawa’s 1965 paper is to right**

→ ***“George Oshawa’s Transmutation Experiments,” East-West Institute Magazine (March 1965)***

Citing Oshawa, Sundaresan and Bockris ultimately published their experimental results in a refereed publication of the American Nuclear Society (ANS) – please see:

→ ***“Anomalous reactions during arcing between carbon rods in water,” R. Sundaresan and J. O’M. Bockris, Fusion Technology 26 pp. 261 – 265 1994***

Note: this journal has since changed its name to “Fusion Science and Technology”

→ *Around that time, Bockris became embroiled in the huge, still ongoing controversy surrounding “cold fusion” and work in the area that he was pursuing at Texas A&M. He relates the tangled tale of that saga in a general science article:*

J. O’M. Bockris,“Accountability and academic freedom – the battle concerning research on cold fusion at Texas A&M University,” Accountability in Research 8 pp. 103-117 2000

It can be found online at: http://www.lenr-canr.org/acrobat/BockrisJaccountabi.pdf

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1994: Texas A&M experiments with carbon-arcs in H_2O - II

Texas A&M repeated Oshawa's work – measured Fe transmutation product

- **Details of Sundaresan & Bockris' 14 experiments were published in *Fusion Technology* paper cited on previous slide**
- **Took extraordinary care to assay, control, and understand initial composition of materials inside the experimental apparatus, particularly with respect to presence of any Fe impurities or other contaminants: e.g., used 6.14 mm diameter 30 cm long Johnson-Matthey AGKSP grade, ultra F purity Carbon rods (Fe impurities verified as 2.03 ppm); started-out with distilled tap water with Fe content of 20 ppb, then purified it even further by passing it thru Millipore-Q ion-exchange columns until resistivity was 13 MΩ – then purified it even further; vessel containing water and C rods was Pyrex glass (see composition to right) trough vessel, etc.**
- **Experimental set-up was straightforward: apparatus consisted of two J-M Carbon (graphite) rods immersed in ordinary water (H_2O). Next, a DC electric current (depending on the experiment, ranging from 12 – 25 A at 10 V) was turned-on and periodically arced between cathode and the anode for 1 – 10 hours. During course of each experiment rod positions were periodically adjusted; arcing was occasionally stopped for a time to allow water to cool-down. At end of an experiment, power was turned-off. Carbon debris lying on the bottom of Pyrex trough was then collected, dried, and analyzed for the presence of Fe by a spectrophotometric method**

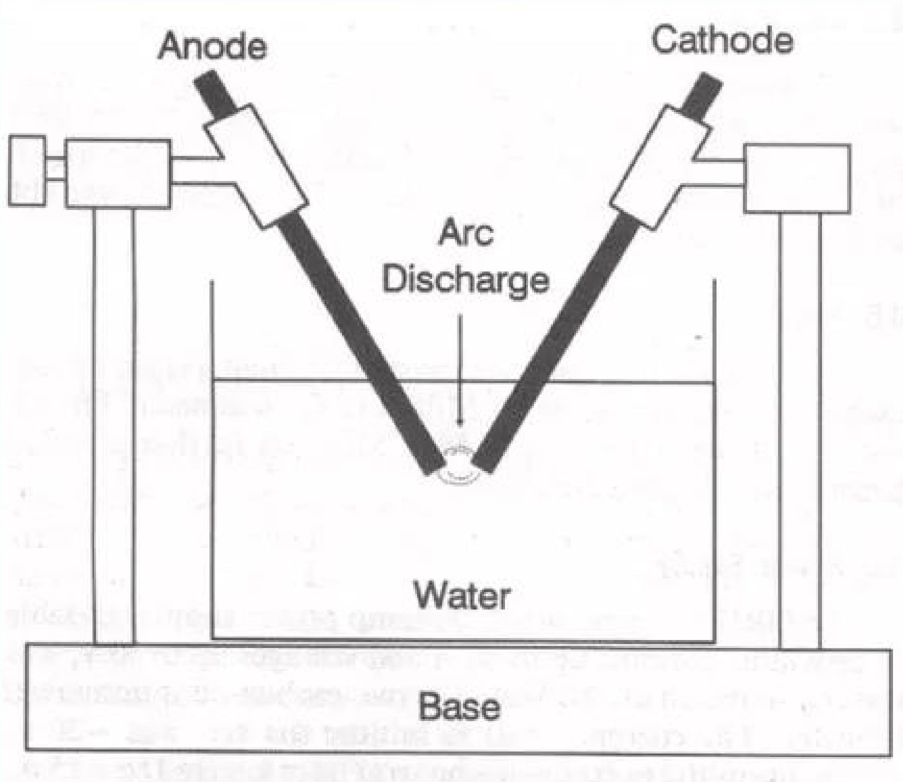

Fig. 1. Holder assembly for the cathode.

Texas A&M Experimental Apparatus
Source: 1994 Fusion Technology paper

Composition of Pyrex Glass
Source: NIST http://physics.nist.gov

Atomic number	Fraction by weight
5- Boron-B	0.040064
8- Oxygen-O	0.539562
11-Sodium-Na	0.028191
13-Aluminum-Al	0.011644
14-Silicon-Si	0.377220
19-Potassium-K	0.003321

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1994: Texas A&M experiments with carbon-arcs in H_2O - III

Table IV - extracted from 1994 Fusion Technology Paper

Note: apologies for tilting of the image

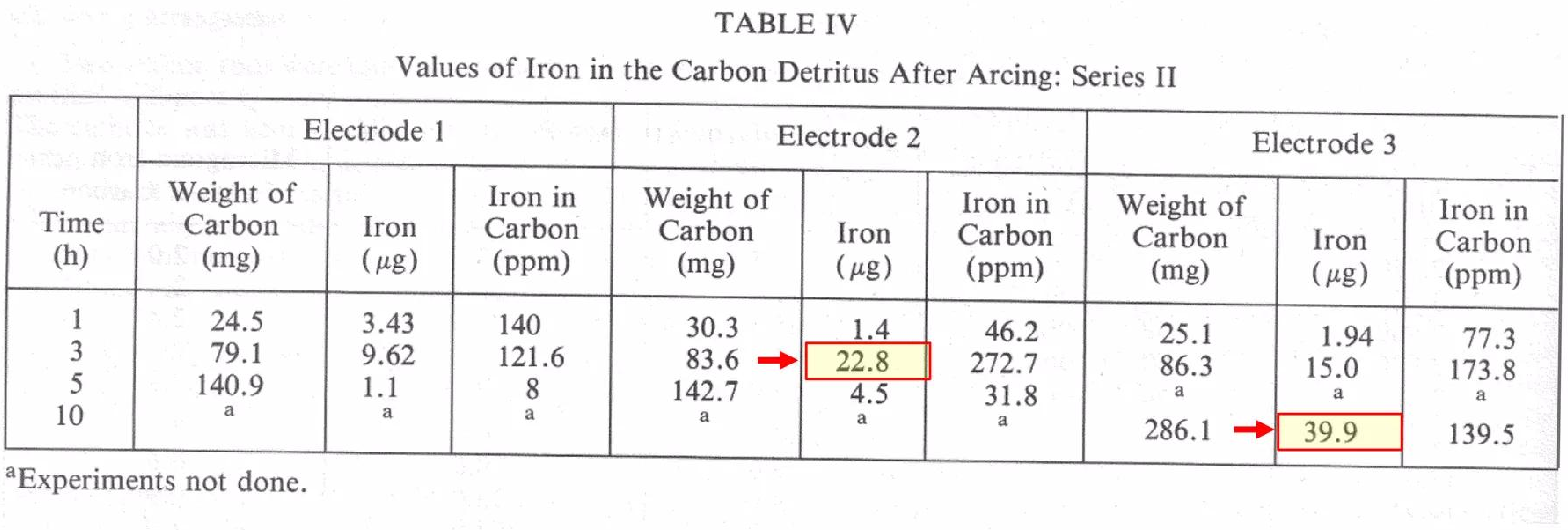

TABLE IV

Values of Iron in the Carbon Detritus After Arcing: Series II

Time (h)	Electrode 1			Electrode 2			Electrode 3		
	Weight of Carbon (mg)	Iron (μg)	Iron in Carbon (ppm)	Weight of Carbon (mg)	Iron (μg)	Iron in Carbon (ppm)	Weight of Carbon (mg)	Iron (μg)	Iron in Carbon (ppm)
1	24.5	3.43	140	30.3	1.4	46.2	25.1	1.94	77.3
3	79.1	9.62	121.6	83.6	22.8	272.7	86.3	15.0	173.8
5	140.9	1.1	8	142.7	4.5	31.8	a	a	a
10	a	a	a	a	a	a	286.1	39.9	139.5

[a]Experiments not done.

Source : Anomalous reactions during arcing between carbon rods in water,"
R. Sundaresan and J. O'M. Bockris, Fusion Technology 26 1994 pp. 264

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1994: Texas A&M experiments with carbon-arcs in H_2O - IV

Discussion and comments on results of Texas A&M experiments - I

- ✓ **No Fe in Pyrex vessel walls. Only possible sources of Fe contamination were from ultrapure C rods, ultrapure H_2O, and/or laboratory air (very unlikely): from a material science standpoint, experiments were very well characterized. Possibility of any rogue Fe contamination was minimized as much as possible**
- ✓ **Sundaresan & Bockris estimated that the total initial pre-experiment quantity of Fe contained in each ultrapure Carbon rod ranged from 20 - 40 µg**
- ✓ **Of the total of 14 experiments conducted, some of their reported results were much more conclusive than others**
- ✓ **In particular, please see Table IV from their paper (shown in previous slide): Electrode 2 – quantity of Iron found in Carbon detritus after 3 hrs measured 22.8 µg; Electrode 3 – quantity of Iron found after 10 hrs measured 39.9 µg**
- ✓ **Majority of both carbon rods remained fully intact at the conclusion of every experiment. For the quantity of Fe observed in C detritus at those times in these two particular experiments to be result of Fe migration from rods <u>rather than</u> being a nuclear transmutation product would require that most if not all of the pre-experiment Iron contained in one or both rods must have somehow diffused and migrated out thru rod tips to end-up in detritus found at the bottom of the Pyrex vessel; by any reasonable standard, such an event would appear unlikely**

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1994: Texas A&M experiments with carbon-arcs in H_2O - V

Discussion and comments on results of Texas A&M's experiments - II

- ✓ **Hoping to explain the Fe transmutation anomaly that had been observed in their experiments, Sundaresan & Bockris speculated that some type of nuclear fusion reaction had occurred, to wit:** $2\ {}_{6}C^{12} + 2\ {}_{8}O^{18} \Rightarrow {}_{26}Fe^{56} + {}_{2}He^{4}$
- ✓ **Under the experimental conditions found in high-current carbon arcs, fusion reactions between Carbon and Oxygen nuclei as shown in above equation are highly improbable; such heavy ions have even higher Coulomb barriers than D-D or D-T fusion reactions. Their explanation for the observed nuclear process was, in the context of W-L theory, incorrect**
- ✓ **In Section IV. "Discussion" on pages 264-265, S&B discussed possibility that they had probably observed nuclear heat production in the form of an 'excessive' increase in measured temperature of water in Pyrex reaction vessel during experiments. Unfortunately, their quantitative measurements of input energy and related ongoing heat production during experiments were relatively crude and incomplete. That being the case, Sundaresan & Bockris' discussion of energetics was highly speculative and not at all quantitatively definitive with regard to elucidating potential reaction mechanisms and nucleosynthetic pathways. Nonetheless, if their observed Fe was truly a transmutation product, there is little doubt that significant amounts of excess heat were produced during the carbon-arc experiments**

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1994: Texas A&M experiments with carbon-arcs in H_2O - VI

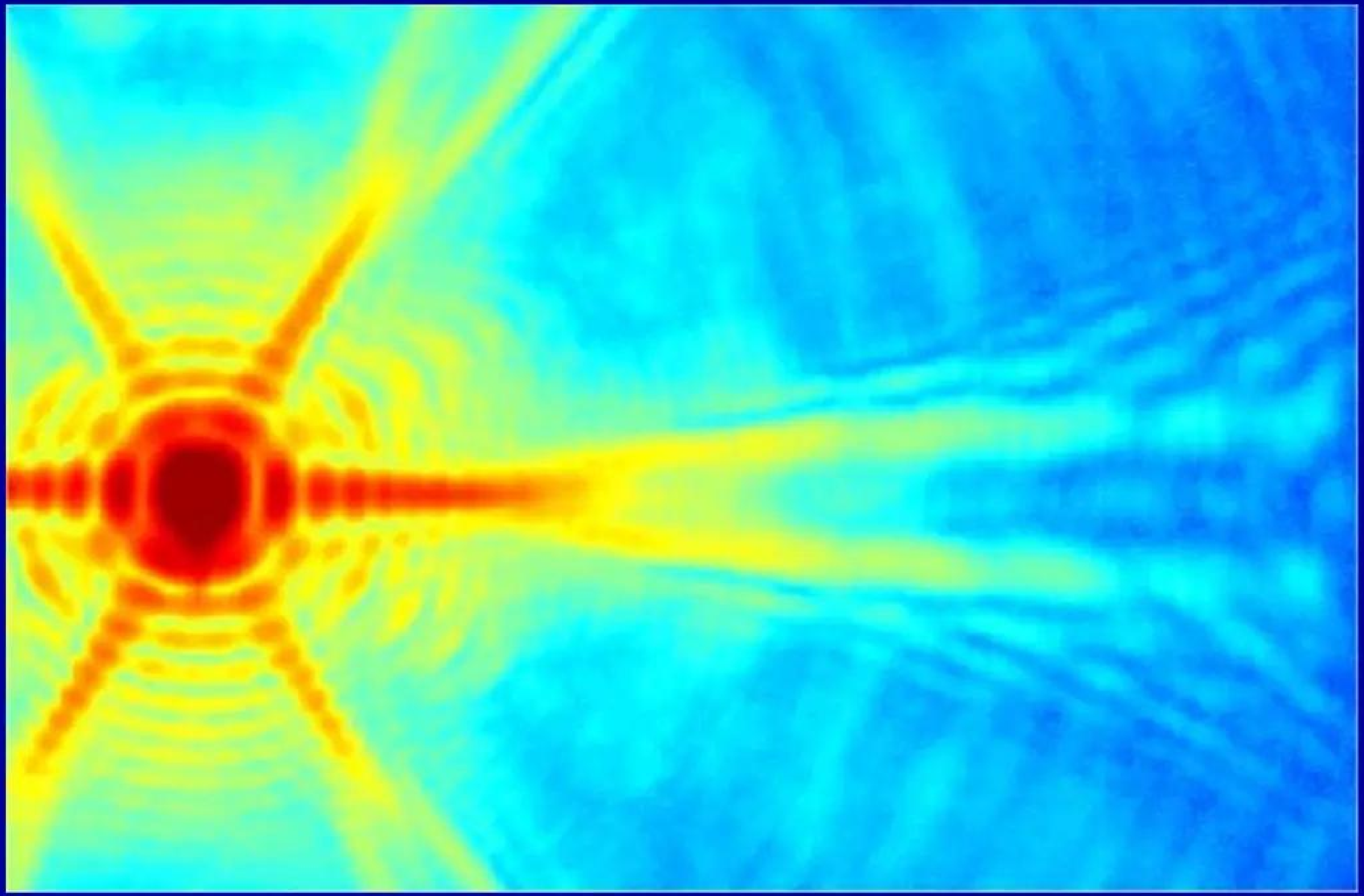
Final comments on results of Texas A&M's experiments - III

- ✓ **Conclusion**: it appears likely that Fe was produced as a nuclear transmutation product arising from Carbon 'seed nuclei' that were present at the beginning of Sundaresan & Bockris' carbon-arc experiments with well-characterized materials
- ✓ **Tip-off that W-L theoretical mechanism was involved**: following Oshawa, S&B verified that anomalous Fe production did not occur when liquid H_2O was replaced with Nitrogen gas. Believing that the nuclear process in carbon-arcs was C-O fusion, they thought absence of Oxygen had prevented fusion reactions; Sundaresan & Bockris did not realize what was really needed were the protons found in water ($e + p \Rightarrow n + \nu$)
- ✓ **Difference**: unlike previously discussed Case Pd/C/D replications conducted at SRI by McKubre et al., neither Palladium (Pd) nor any other noble metal was present in significant quantities in S&B's experimental system; appreciable amounts of Deuterium (D) were also absent from the Texas A&M carbon-arc H_2O experiments
- ✓ **Key questions**: was a higher-A extension of the carbon-seed LENR ULMN-catalyzed nucleosynthetic network shown in Slides #11–12 also operating in S&B's carbon-arc experimental system? Can the Widom-Larsen theory of LENRs explain anomalous Fe production that occurs in carbon-arc light water experiments --- if so, exactly how?
- ✓ **Answer**: yes to all - in the next section we will discuss very similar experiments that were conducted at BARC (India) at around the same time (importantly, they obtained the same results as S&B) and illustrate one of a large number of possible LENR ULMN-driven nucleosynthetic pathways that can explain the observed Fe and other transmutation products comfortably within the overall framework of W-L theory

Review and discussion of LENR experiments - III

Primarily non-metallic Carbon substrates hosting nuclear-active sites

1994: BARC carbon-arc/H_2O; Singh et al.



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1994: BARC experiments with carbon-arcs in H_2O - I

BARC (India) conducts experiments very similar to those at Texas A&M

- ✓ **Details of Singh et al.'s experiments were published in 1994 *Fusion Technology* paper cited to right**
- ✓ **Like S&B, also took great care to assay, control, and try to understand the initial composition of materials inside their experimental apparatus, especially with respect to presence of any Fe impurities or other contaminants: e.g., used 6.0 mm dia., 30 cm long Ultra Carbon Corporation ultra-high-purity Carbon rods (Fe impurities certified at < 2 ppm); also used ultrapure deionized water (H_2O) in experiments**
- ✓ **DC electric current (depending on experiment, ranged from 10 A up to 28 A at 30 - 35 V) was turned-on and periodically arced between cathode and the anode for total arcing times of 1- 20 hours. During each experiment rod positions were adjusted; arcing was occasionally stopped for a time to allow water bath cool-down. At the end of an experiment, power was turned-off. Carbon debris lying on the bottom of Pyrex trough was collected, dried, and analyzed for presence of Fe by a spectrographic method**

➡ *References*: ***"Verification of the George Oshawa experiment for anomalous production of iron from Carbon arc in water," M. Singh, M. Saksena, V. Dixit, and V. Kartha, Fusion Technology 26 pp. 266 – 270 1994***

Note: this refereed ANS journal has since changed its name to "Fusion Science and Technology"

➡ *BARC is an acronym for the famous Bhabha Atomic Research Center in Bombay, India; it is a government nuclear laboratory akin to a cross between Los Alamos and Sandia in the US. For more information, please see Wikipedia article:*

http://en.wikipedia.org/wiki/Bhabha_Atomic_Research_Centre

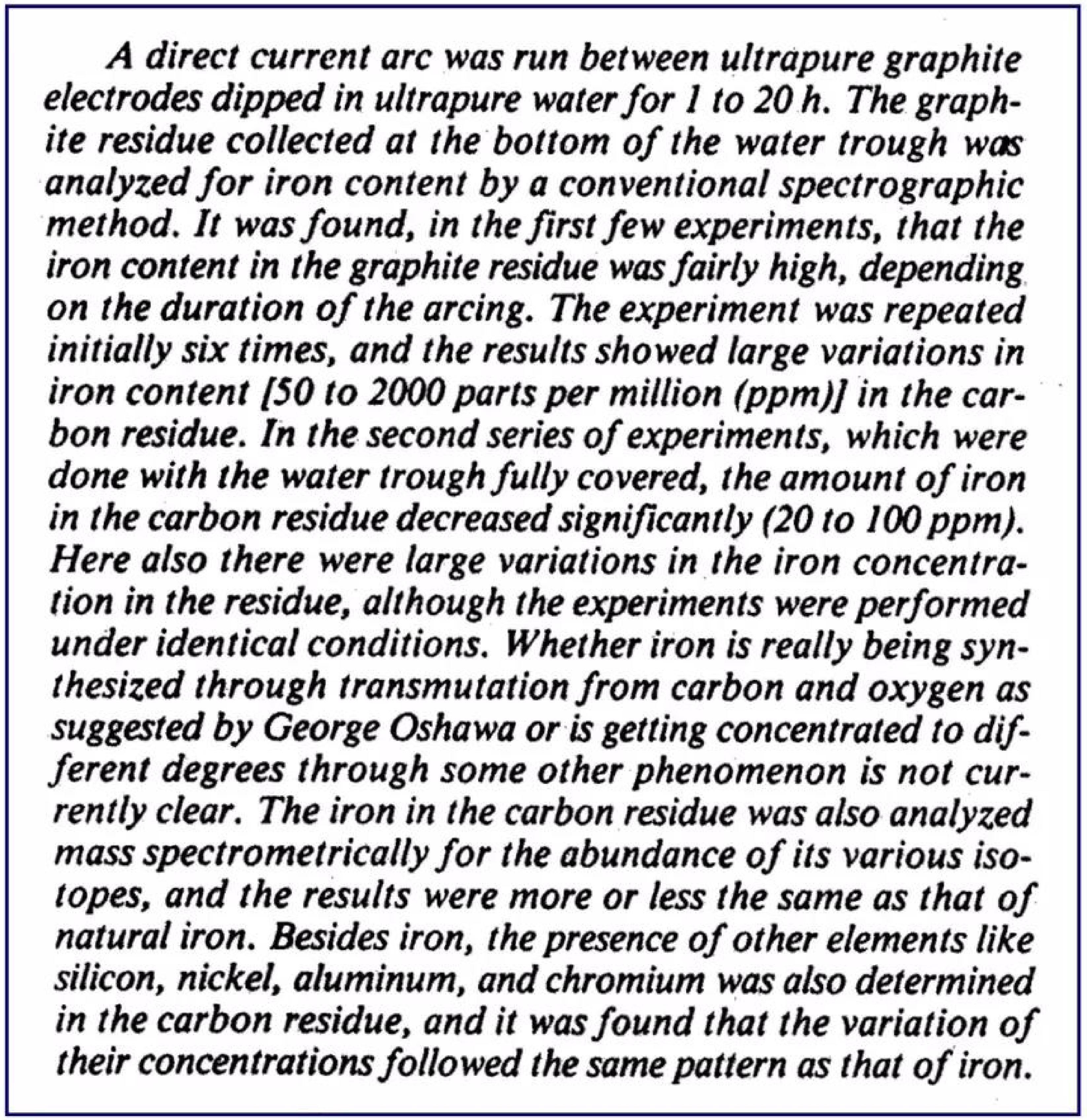
From 1989 through ca.1995 when all Indian R&D in LENRs was deliberately stopped, BARC scientists had reported many interesting results. Much of the early BARC work thru late 1989 can be found in:

➡ ***"BARC Studies in Cold Fusion," P.K. Iyengar and M. Srinivsan, eds., Gov't of India, Atomic Energy Commission, December 1989 (153 pages – 30 MB)***

Which can be downloaded online from NET at: ***http://www.newenergytimes.com/v2/archives/1989BARC1500Report/1500.shtml***

1994: BARC experiments with carbon-arcs in H_2O - II

Abstract and Fig. 1 from paper by Singh et al. in Fusion Technology 26 (1994)



A direct current arc was run between ultrapure graphite electrodes dipped in ultrapure water for 1 to 20 h. The graphite residue collected at the bottom of the water trough was analyzed for iron content by a conventional spectrographic method. It was found, in the first few experiments, that the iron content in the graphite residue was fairly high, depending on the duration of the arcing. The experiment was repeated initially six times, and the results showed large variations in iron content [50 to 2000 parts per million (ppm)] in the carbon residue. In the second series of experiments, which were done with the water trough fully covered, the amount of iron in the carbon residue decreased significantly (20 to 100 ppm). Here also there were large variations in the iron concentration in the residue, although the experiments were performed under identical conditions. Whether iron is really being synthesized through transmutation from carbon and oxygen as suggested by George Oshawa or is getting concentrated to different degrees through some other phenomenon is not currently clear. The iron in the carbon residue was also analyzed mass spectrometrically for the abundance of its various isotopes, and the results were more or less the same as that of natural iron. Besides iron, the presence of other elements like silicon, nickel, aluminum, and chromium was also determined in the carbon residue, and it was found that the variation of their concentrations followed the same pattern as that of iron.

Source: *Fusion Technology* 26 pp. 266 (1994)

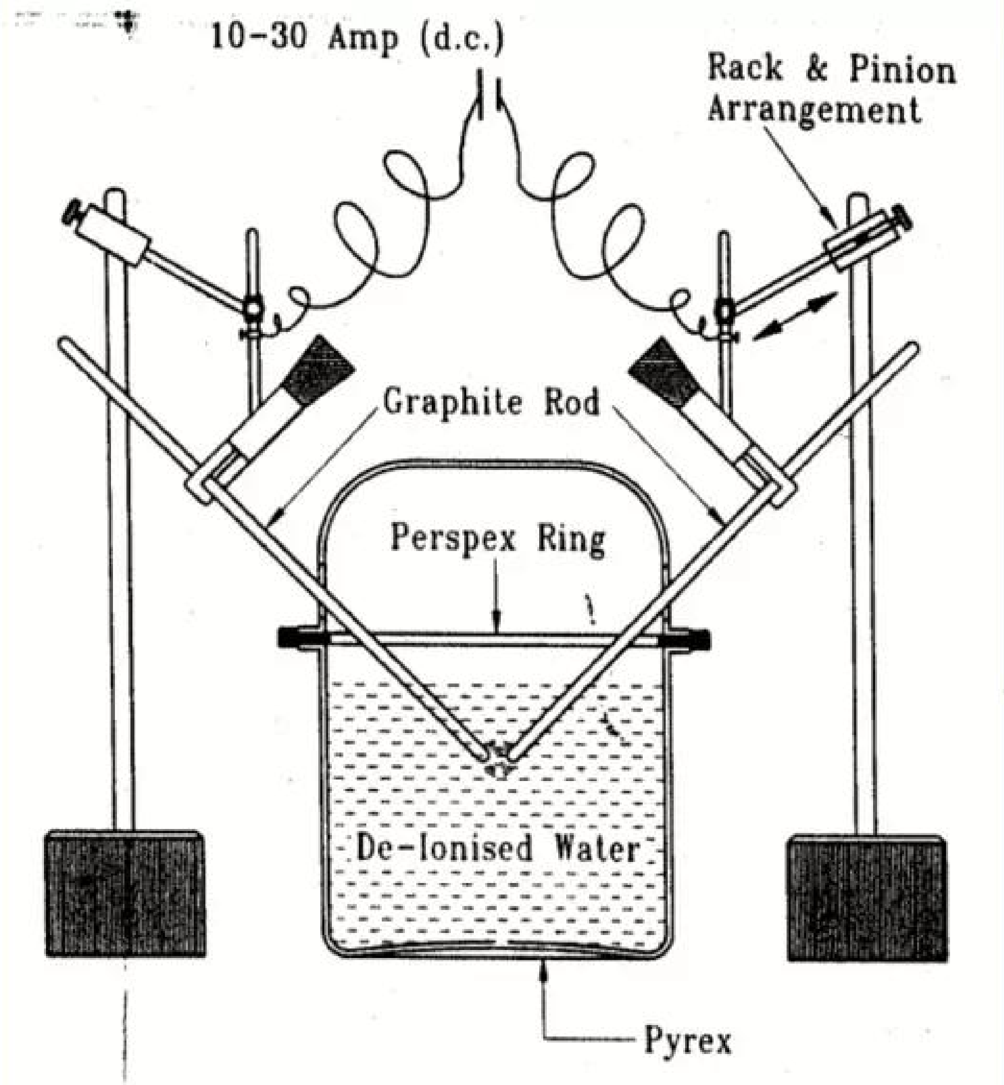


Fig. 1. Experimental setup of carbon arc in water.

Source: *Fusion Technology* 26 pp. 267 (1994)

Please note similarity with carbon-arc apparatus used by Sundaresan and Bockris as shown in Slide #40

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1994: BARC experiments with carbon-arcs in H_2O - III

Table I from paper by Singh et al. in Fusion Technology 26 (1994)

Note: apologies for tilting of the image

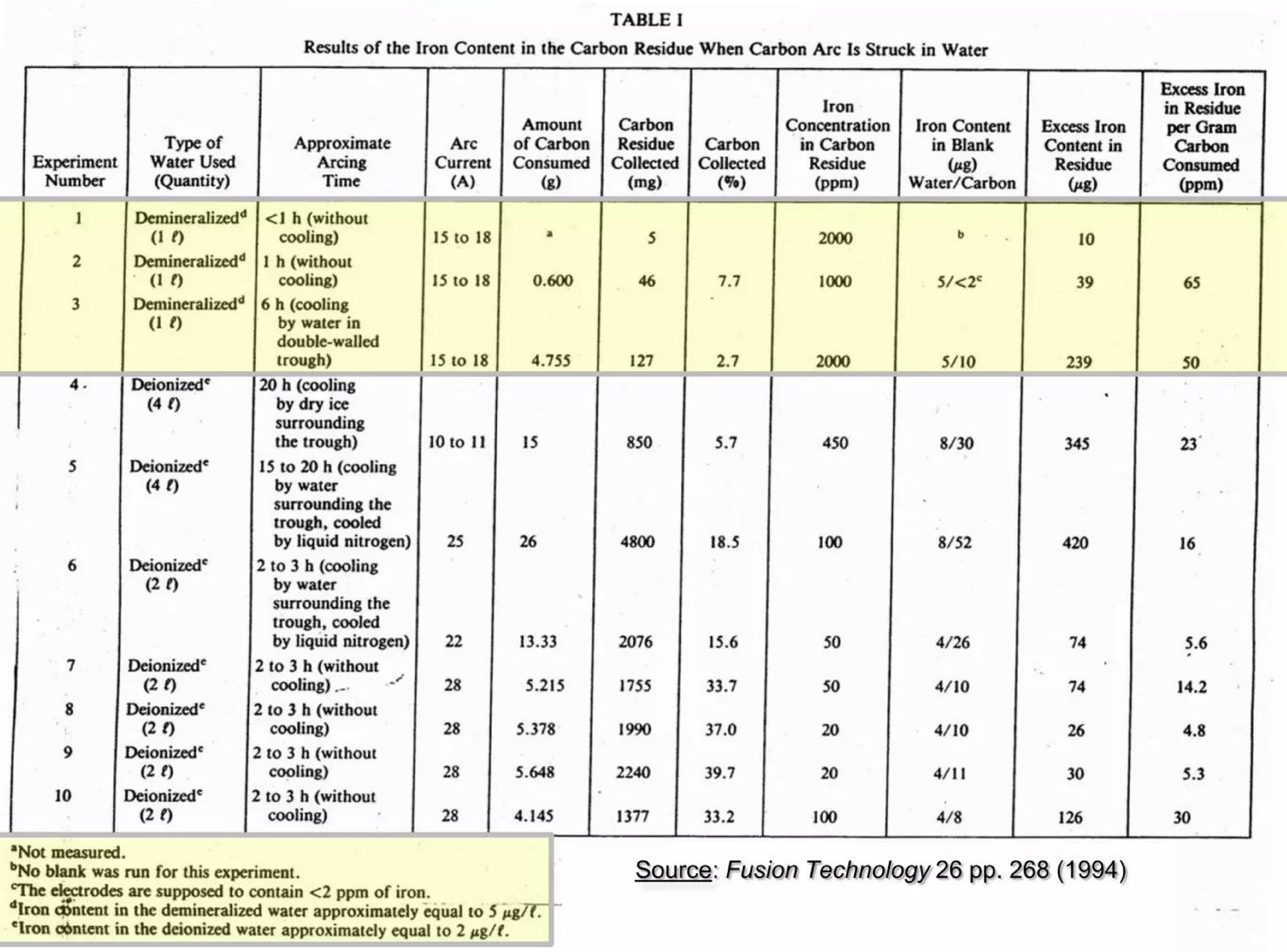

TABLE I

Results of the Iron Content in the Carbon Residue When Carbon Arc Is Struck in Water

Experiment Number	Type of Water Used (Quantity)	Approximate Arcing Time	Arc Current (A)	Amount of Carbon Consumed (g)	Carbon Residue Collected (mg)	Carbon Collected (%)	Iron Concentration in Carbon Residue (ppm)	Iron Content in Blank (μg) Water/Carbon	Excess Iron Content in Residue (μg)	Excess Iron in Residue per Gram Carbon Consumed (ppm)
1	Demineralized[d] (1 ℓ)	<1 h (without cooling)	15 to 18	[a]	5		2000	[b]	10	
2	Demineralized[d] (1 ℓ)	1 h (without cooling)	15 to 18	0.600	46	7.7	1000	5/<2[c]	39	65
3	Demineralized[d] (1 ℓ)	6 h (cooling by water in double-walled trough)	15 to 18	4.755	127	2.7	2000	5/10	239	50
4	Deionized[e] (4 ℓ)	20 h (cooling by dry ice surrounding the trough)	10 to 11	15	850	5.7	450	8/30	345	23
5	Deionized[e] (4 ℓ)	15 to 20 h (cooling by water surrounding the trough, cooled by liquid nitrogen)	25	26	4800	18.5	100	8/52	420	16
6	Deionized[e] (2 ℓ)	2 to 3 h (cooling by water surrounding the trough, cooled by liquid nitrogen)	22	13.33	2076	15.6	50	4/26	74	5.6
7	Deionized[e] (2 ℓ)	2 to 3 h (without cooling)	28	5.215	1755	33.7	50	4/10	74	14.2
8	Deionized[e] (2 ℓ)	2 to 3 h (without cooling)	28	5.378	1990	37.0	20	4/10	26	4.8
9	Deionized[e] (2 ℓ)	2 to 3 h (without cooling)	28	5.648	2240	39.7	20	4/11	30	5.3
10	Deionized[e] (2 ℓ)	2 to 3 h (without cooling)	28	4.145	1377	33.2	100	4/8	126	30

[a] Not measured.
[b] No blank was run for this experiment.
[c] The electrodes are supposed to contain <2 ppm of iron.
[d] Iron content in the demineralized water approximately equal to 5 μg/ℓ.
[e] Iron content in the deionized water approximately equal to 2 μg/ℓ.

Source: *Fusion Technology* 26 pp. 268 (1994)

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1994: BARC experiments with carbon-arcs in H_2O - IV

Table III from paper by Singh et al. in Fusion Technology 26 (1994)

<u>Note</u>: apologies for tilting of the image

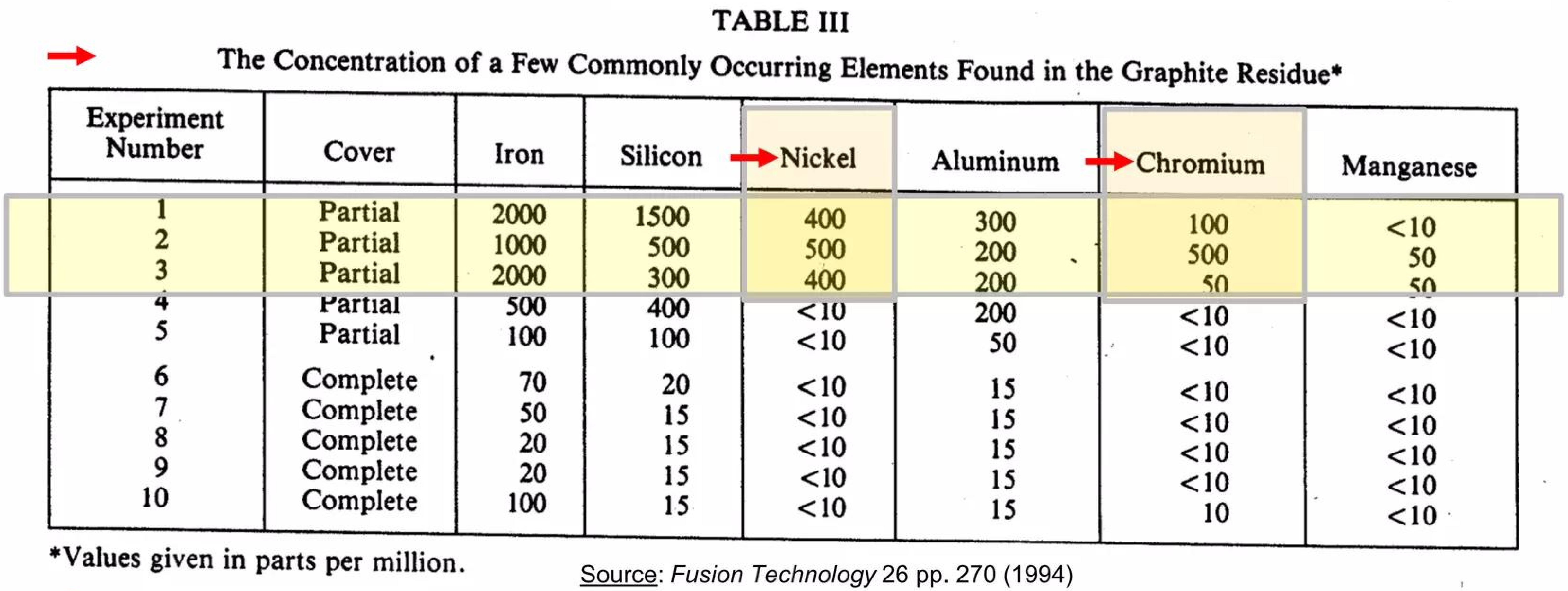

TABLE III

→ The Concentration of a Few Commonly Occurring Elements Found in the Graphite Residue*

Experiment Number	Cover	Iron	Silicon	→ Nickel	Aluminum	→ Chromium	Manganese
1	Partial	2000	1500	400	300	100	<10
2	Partial	1000	500	500	200	500	50
3	Partial	2000	300	400	200	50	50
4	Partial	500	400	<10	200	<10	<10
5	Partial	100	100	<10	50	<10	<10
6	Complete	70	20	<10	15	<10	<10
7	Complete	50	15	<10	15	<10	<10
8	Complete	20	15	<10	15	<10	<10
9	Complete	20	15	<10	15	<10	<10
10	Complete	100	15	<10	15	10	<10

*Values given in parts per million.

<u>Source</u>: *Fusion Technology* 26 pp. 270 (1994)

→ **Composition of Pyrex Glass**
Source: NIST http://physics.nist.gov

Atomic number	Fraction by weight
5- Boron-B	0.040064
8- Oxygen-O	0.539562
11-Sodium-Na	0.028191
13-Aluminum-Al	0.011644
14-Silicon-Si	0.377220
19-Potassium-K	0.003321

→ **<u>Please note</u>: Experiments #1 – 3 used demineralized rather than deionized H_2O (see previous Slide). Reaction vessel is composed of Pyrex glass, which does contain Boron, Oxygen, Sodium, Aluminum, Silicon, and Potassium. However, Pyrex does <u>not</u> contain Nickel or Chromium, nor are those elements present in appreciable quantities in the carbon rods, demineralized or deionized water, or air prior to the beginning of the carbon-arc experiments of Singh et al.**

1994: BARC experiments with carbon-arcs in H_2O - V

Discussion of Singh et al.'s carbon-arc experiments at BARC - I

- ✓ **In their experimental procedures, Singh et al. also took extraordinary precautions to try to eliminate and/or control potential sources of elemental contamination that could create 'false positives' in their assays for presence of potential LENR transmutation products**
- ✓ **Please see Table III shown on the previous slide. Note that under the stated experimental conditions, from a chemical reactivity perspective it is unlikely that significant amounts of Boron, Oxygen, Sodium, Silicon, Aluminum, and/or Potassium 'leached-out' of the Pyrex glass into the water and were then subsequently ad/absorbed into the Carbon detritus that collected at bottom of the reaction vessel. For the moment, let us simply put those elements aside in deference to the most die-hard skeptics of LENRs. However, what remains are Nickel and Chromium - in significant quantities no less**
- ✓ **At the beginning of their experiments, there was no appreciable Ni and/or Cr present in the Carbon rods, water, Pyrex vessel, or in the laboratory air. Unless their spectrographic analyses were erroneous, only remaining possibility is that Ni and Cr were transmutation products**

→ *"No phenomenon is a real phenomenon until it is an observed phenomenon."*

"If you haven't found something strange during the day, it hasn't been much of a day.

John Wheeler, coined term "black hole" in 1967

"These are very deep waters."

Sherlock Holmes, "The Adventure of the Speckled Band" (1892)

"It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."

Sherlock Holmes, "A Scandal in Bohemia" (1891)

"There is nothing as deceptive as an obvious fact."

Sherlock Holmes, "The Boscombe Valley Mystery," (1891)

"Facts do not cease to exist because they are ignored."

Aldous Huxley, "Proper Studies" (1927)

" … when you have eliminated the impossible, whatever remains, however improbable, must be the truth."

Sherlock Holmes, "The Sign of the Four," (1890)

1994: BARC experiments with carbon-arcs in H_2O - VI

Discussion of Singh et al.'s carbon-arc experiments at BARC - II

- ✓ **While production of Ni and Cr appear to constitute harder-to-argue-with scientific evidence for the occurrence of nuclear transmutations, Fe mass balances observed and measured in Singh et al.'s BARC experiments also support the conclusion**
- ✓ **Please see data in Table I on Slide #48. Their analysis of experimental data (pp. 269) was as follows: each ultrapure Carbon rod had a measured mass in grams at the start of a given experiment. Column 5 in Table I, "Amount of Carbon Consumed (g)" is a C rod's initial mass minus its carefully measured mass at the end of an experiment. The mass of carbonaceous material collected as particulate debris found at the bottom of the Pyrex reaction vessel at end of an experiment is shown in column 6, "Carbon Residue Collected (mg)." In column 7, "Carbon collected (%)", the mass of carbon residue divided by the mass of carbon consumed is expressed as a %. Results of the spectrographic analysis of the collected residue with respect to Fe concentration expressed in parts per million (ppm) are shown in column 8, "Iron Concentration in Residue (ppm)." The total mass of Fe impurities estimated to be present in the entire volume of water in the vessel (see footnotes d and e in Table III) and the total mass of Fe estimated to be present as an impurity in the entire portion of a carbon rod that was consumed during an experiment (column 5) are shown in column 9, "Iron Content in Blank (μg) Water/Carbon." Subtracting the total mass of Fe impurities estimated in column 9 from the total mass of Fe measured spectrographically in the residue (column 8) allowed them to calculate the total mass of anomalous Iron produced in an experiment in column 10, "Excess Iron Content in Residue (μg)." Lastly, column 10 shows the, "Excess iron in Residue per Gram of Carbon Consumed (ppm)"**

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1994: BARC experiments with carbon-arcs in H_2O - VII

Discussion of Singh et al.'s carbon-arc experiments at BARC - III

- ✓ **Estimates of excess iron content found in carbonaceous debris that were produced during BARC experiments would appear to be relatively conservative (column 10 in Table I on pp. 268 of Singh et al.'s Fusion Technology paper). That being the case, unless there were incredibly large systematic errors in measurements of masses, it is hard to imagine anything other than nuclear transmutations that could possibly have produced the observed experimental data**
- ✓ **In the case of BARC experiments # 1 – 3, production of anomalous "excess iron" occurred in parallel with production of significant amounts of anomalous Ni and Cr, neither of which were present in any materials within the apparatus at the beginning of experiments. By any reasonable standard, simultaneous production of all three anomalous elemental products within less than six hours of arcing in apparatus containing compositionally well-characterized materials appears to be strong experimental evidence for operation of LENR nucleosynthetic transmutation pathways, to wit: C⇨Cr⇨Fe⇨Ni**
- ✓ **Since some experiments were not covered, could atmospheric dust have somehow contaminated the water in the Pyrex vessel and thus produced all of these anomalous results? Maybe, but that idea stretches reason even further than the possibility of transmutations**

→ ***Ultrapure carbon rods*:**
Carbon/graphite rods virtually identical to those used in these experiments are still readily available for interested LENR experimentalists

Ted Pella, Inc. of Redding, CA has them available for sale on its company website at:

→ ***http://www.tedpella.com/carbon_html/carbon1.htm***

Their physical characteristics are as follows:

Density: 2.2 gm cm^{-3}
Melting Point: around 3550°C
Evaporation Temp.: 2400°C

→ ***"Spec-pure":***
(spectroscopically pure) grade is available for carbon (graphite) rods with impurities equal or less than 2ppm (single element 1 ppm or less)

Prod. # 61 – 15: Carbon Rods, Grade 1 Spec-Pure, 1/4" x 12" (6.2 x 304 mm) pkg/12 $54.30

1994: BARC experiments with carbon-arcs in H_2O - VIII

Discussion of Singh et al.'s carbon-arc experiments at BARC - IV

- ✓ **Experimental error**: Singh et al. estimated the experimental error in their spectrographic measurements of ppm concentrations of detected elements (e.g., Fe) for which they had standards and calibration curves as +/- 15% to 20%. In the case of experiments #1 - #4 (Table I - Fe concentration in carbon debris residue in ppm: 2000, 1000, 2000, and 450, respectively) ppm concentrations of Fe were large enough so that even a worst-case 20% measurement error would not alter the conclusion that anomalous Fe had been observed
- ✓ **Mass spectroscopy analysis of anomalous iron**: In Table II on pp. 269 Singh et al. show results of mass spectroscopic analysis of Fe isotopes in the anomalous iron found in carbonaceous particulate debris at the bottom of the Pyrex reaction vessel. Observed Fe isotope ratios shown in Table II were unremarkable in that they did not differ significantly from natural terrestrial abundances. In context of ULM neutron-catalyzed LENRs a la W-L theory, this result is not surprising. Fe's natural abundance values are end-result of a composite of several episodes of neutron-catalyzed r-/s-process nucleosynthesis occurring over billions of years; they reflect Nature's 'optimization' of element nucleosynthesis. A priori, why should LENRs be different?
- ✓ **Irrefutable fact**: prosaic chemical processes cannot produce nuclear transmutations in any type of closed experimental system; elements previously absent do not just suddenly appear
- ✓ **Conclusion**: again, as the fictional Sherlock Holmes said, "When you have eliminated the impossible, whatever remains, however improbable, must be the truth." Based on our reanalysis of their data in the context of the W-L theory of LENRs, the most reasonable explanation is that both Sundaresan & Bockris and Singh et al. probably observed LENR nuclear transmutations in their ca. 1994 carbon-arc experiments at Texas A&M and BARC

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1994: BARC experiments with carbon-arcs in H_2O - IX

BARC/Texas A&M transmutation results in light of W-L theory of LENRs

- ✓ **We will now apply W-L theory to help shed some light on the experimental transmutation results of Bockris & Sundaresan and Singh et al.**
- ✓ **First, we will sketch-out a W-L LENR ULM neutron-catalyzed nucleosynthetic network pathway that could produce the observed transmutation products from C-seed nuclei**
- ✓ **Please note that this W-L-based theoretical path illustrates only one of a multitude of energetically viable potential pathways that could produce the observed carbon-arc transmutation product results; uncovering all the fine details of everything that may have really happened in the experiments would require exhaustive assays and isotopic analyses of all detectable nuclear products as well as computerized network codes that can mimic reaction dynamics of an LENR network as it evolves over time. Unfortunately, neither the detailed data nor the computer codes are presently available to assist us**
- ✓ **Nonetheless, it is hoped that this illustrative model network pathway will demonstrate the plausibility of producing the observed transmutation products in the amount of reaction time available under experimental conditions that occur in H_2O carbon-arcs**
- ✓ **Last, we will propose a new hypothesis to answer a question posed on Slide #44: in the absence of hydride-forming metals such as Pd or Ti inside the carbon-arc apparatus, can the Widom-Larsen theory of LENRs still explain the observed experimental results?**

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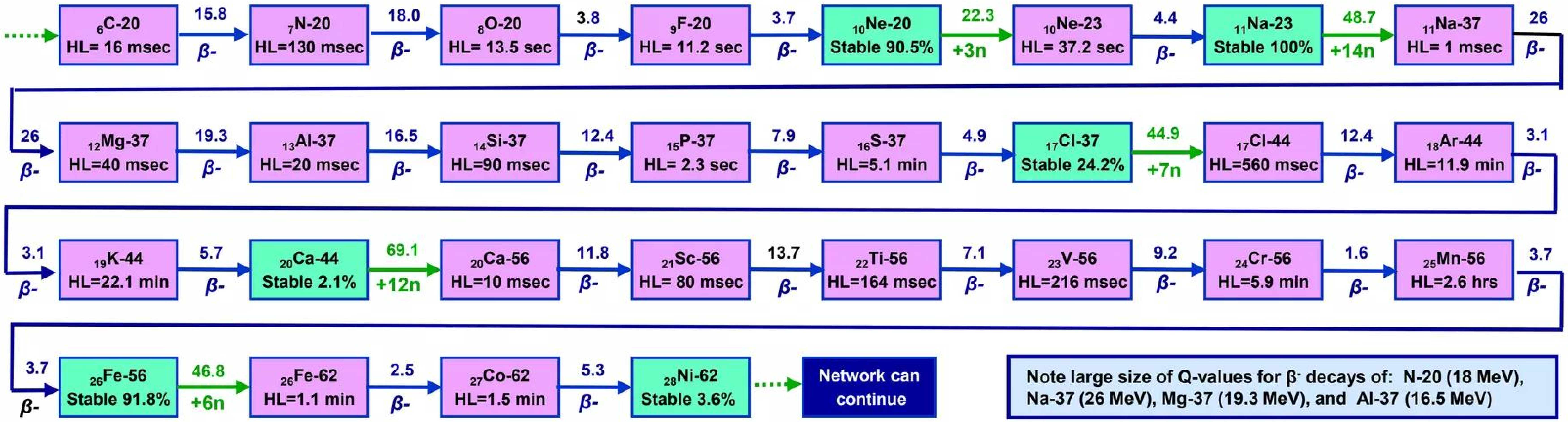
1994: BARC experiments with carbon-arcs in H_2O - X

LENR nucleosynthetic pathway from Carbon to Iron begins with C-20

Note: this illustrative model path begins at C-20 in carbon-seed LENR network shown on Slide #12



${}_{6}$C-20 HL= 16 msec → 15.8 β- → ${}_{7}$N-20 HL=130 msec → 18.0 β- → ${}_{8}$O-20 HL= 13.5 sec → 3.8 β- → ${}_{9}$F-20 HL= 11.2 sec → 3.7 β- → ${}_{10}$Ne-20 Stable 90.5% → 22.3 +3n → ${}_{10}$Ne-23 HL= 37.2 sec → 4.4 β- → ${}_{11}$Na-23 Stable 100% → 48.7 +14n → ${}_{11}$Na-37 HL= 1 msec → 26 β-

→ ${}_{12}$Mg-37 HL=40 msec → 19.3 β- → ${}_{13}$Al-37 HL=20 msec → 16.5 β- → ${}_{14}$Si-37 HL=90 msec → 12.4 β- → ${}_{15}$P-37 HL= 2.3 sec → 7.9 β- → ${}_{16}$S-37 HL=5.1 min → 4.9 β- → ${}_{17}$Cl-37 Stable 24.2% → 44.9 +7n → ${}_{17}$Cl-44 HL=560 msec → 12.4 β- → ${}_{18}$Ar-44 HL=11.9 min → 3.1 β-

→ ${}_{19}$K-44 HL=22.1 min → 5.7 β- → ${}_{20}$Ca-44 Stable 2.1% → 69.1 +12n → ${}_{20}$Ca-56 HL=10 msec → 11.8 β- → ${}_{21}$Sc-56 HL= 80 msec → 13.7 β- → ${}_{22}$Ti-56 HL=164 msec → 7.1 β- → ${}_{23}$V-56 HL=216 msec → 9.2 β- → ${}_{24}$Cr-56 HL=5.9 min → 1.6 β- → ${}_{25}$Mn-56 HL=2.6 hrs → 3.7 β-

→ ${}_{26}$Fe-56 Stable 91.8% → 46.8 +6n → ${}_{26}$Fe-62 HL=1.1 min → 2.5 β- → ${}_{27}$Co-62 HL=1.5 min → 5.3 β- → ${}_{28}$Ni-62 Stable 3.6% → Network can continue

Note large size of Q-values for β^- decays of: N-20 (18 MeV), Na-37 (26 MeV), Mg-37 (19.3 MeV), and Al-37 (16.5 MeV)

Legend:

All reactions proceed from left to right; Q-value for a given reaction or for a group of neutron captures is in MeV and is located on top of the blue or green horizontal arrows

Beta decays are denoted with a dark blue horizontal arrow; ULM neutron captures are denoted with dark green horizontal arrow – if more than one ULM neutron is captured, the total number of neutrons being captured by the isotope is indicated below the green arrow

Stable isotopes (incl. % abundance) indicated by green colored boxes; unstable isotopes indicated by purplish colored boxes; when measured, half-lives are shown as “HL = xx”

Gamma emissions not shown; per W-L theory, they are automatically converted directly into infrared by heavy SPP electrons; β-delayed decays also not shown (neutron emissions into local continuum tend to be suppressed because of density of occupied fermionic states)

Total ‘gross’ Q_v from C-20 thru Fe-56= 385.7 MeV

Sum of HLs from C-20 thru Fe-56 = ~3.4 hrs

Comments:

Stable nuclei produced by this particular reaction pathway typically have high natural abundances, e.g., Ne, Na, Fe

Sum of half-lives from C-20 to Fe-56 is a little more than three hours; isotope with the longest half-life is just before Fe-56: Mn-56, which is the key ‘gateway isotope’ in this nucleosynthetic path. Practically, this means that: (a) *some* Fe-56 will be synthesized within an hour or so after ULM neutron production begins; and (b) within 5 – 6 hours after ULMN production ends (for whatever reason), many reaction products will have decayed into stable isotopes

1994: BARC experiments with carbon-arcs in H_2O - XI

LENR nucleosynthetic pathway from Carbon to Iron

Comments:

- ✓ **Unlike SRI Case replications, ULM neutron fluxes in high-current carbon-arc experiments were high enough to pass through Fluorine 'valley of death' (i.e., >10^{10} ULMNs cm^2/sec)**
- ✓ **Please recognize that this model example represents but one of many possible LENR nucleosynthetic pathways from Carbon to Iron; final product results observed in a given experiment al run reflect a sum total across many parallel alternate reaction paths**
- ✓ **ULM neutron production occurs near the carbon rod tips and on nanoparticles floating in the water in regions of high currents and electric fields that form between the two C rods; once a particular piece of matter leaves such a region, neutron production stops quickly. Detritus lying on the bottom of a reaction vessel is simply undergoing radioactive decays**
- ✓ **If the data of Sundaresan & Bockris and Singh et al. are correct, the only way that Iron can be produced from Carbon that quickly (becoming analytically detectable within an hour or two) is via nucleosynthetic paths that involve extremely neutron-rich isotopes**
- ✓ **Model pathway on the previous slide clearly illustrates how LENRs can release a great deal of energy in the form of heat without producing deadly gammas or long-lived radioactive isotopes. In that example, the nucleosynthetic path releases ~386 MeV - almost twice the energy of a fission reaction (~190 MeV) slowly over a period of hours**

"THE FORMATION OF FULLERENES: CLUES FROM NEW C_{60}, C_{70}, AND (POSSIBLE) PLANAR C_{24} [Graphene] DETECTIONS IN MAGELLANIC CLOUD PLANETARY NEBULAE"

D. A. García-Hernández *et al.*

The Astrophysical Journal 737 L30 (2011)

http://iopscience.iop.org/2041-8205/737/2/L30/

Free preprint: **http://arxiv.org/pdf/1107.2595v1.pdf**

"We present ten new Spitzer detections of fullerenes in Magellanic Cloud Planetary Nebulae, including the first extragalactic detections of the C70 molecule. These new fullerene detections together with the most recent laboratory data permit us to report an accurate determination of the C60 and C70 abundances in space. Also, we report evidence for the possible detection of planar C24 [Graphene] in some of our fullerene sources, as indicated by the detection of very unusual emission features coincident with the strongest transitions of this molecule at ~6.6, 9.8, and 20 *μm*. The infrared spectra display a complex mix of aliphatic and aromatic species such as hydrogenated amorphous carbon grains (HACs), PAH clusters, fullerenes, and small dehydrogenated carbon clusters (possible planar C24). The coexistence of such a variety of molecular species supports the idea that fullerenes are formed from the decomposition of HACs. We propose that fullerenes are formed from the destruction of HACs, possibly as a consequence of shocks driven by the fast stellar winds, which can sometimes be very strong in transition sources and young PNe. This is supported by the fact that many of our fullerene-detected PNe show altered [NeIII]/[NeII] ratios suggestive of shocks as well as P-Cygni profiles in their UV lines indicative of recently enhanced mass loss."

Image source: ***Nanolasers based on nanowires and surface plasmons,"*** **C. Ning, *SPIE Newsroom* article 10.1117/2.1200901.1486 (January 30, 2009)**
http://nanophotonics.asu.edu/paper/CZNing_SPIE_newsroom09.pdf